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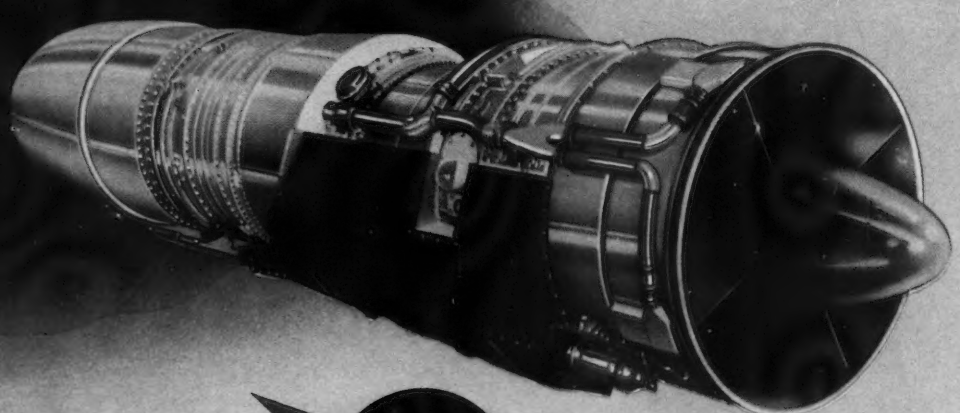

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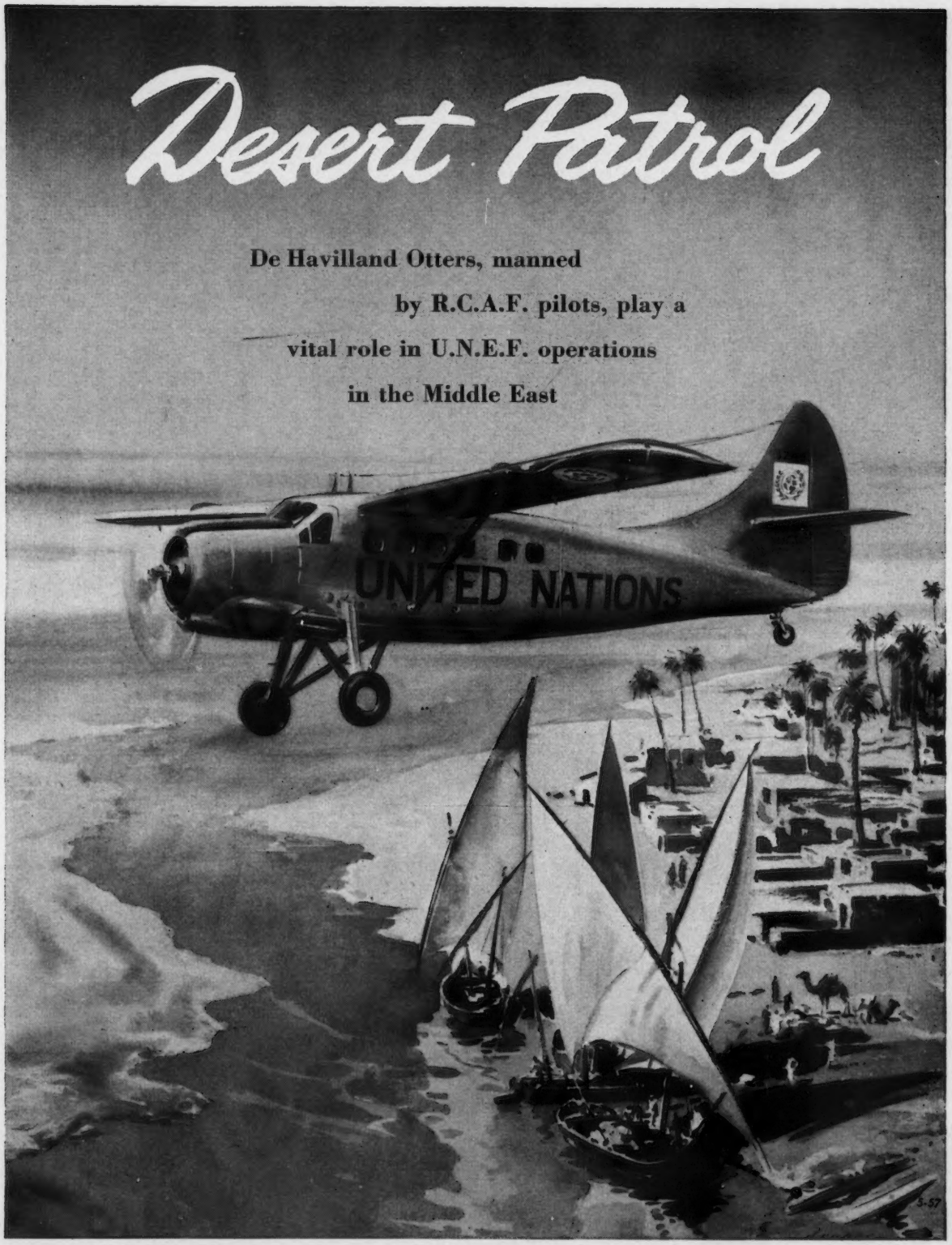

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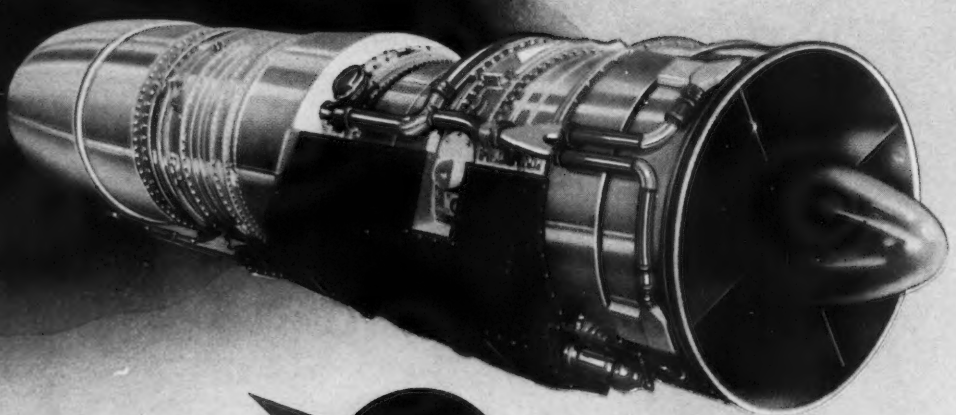

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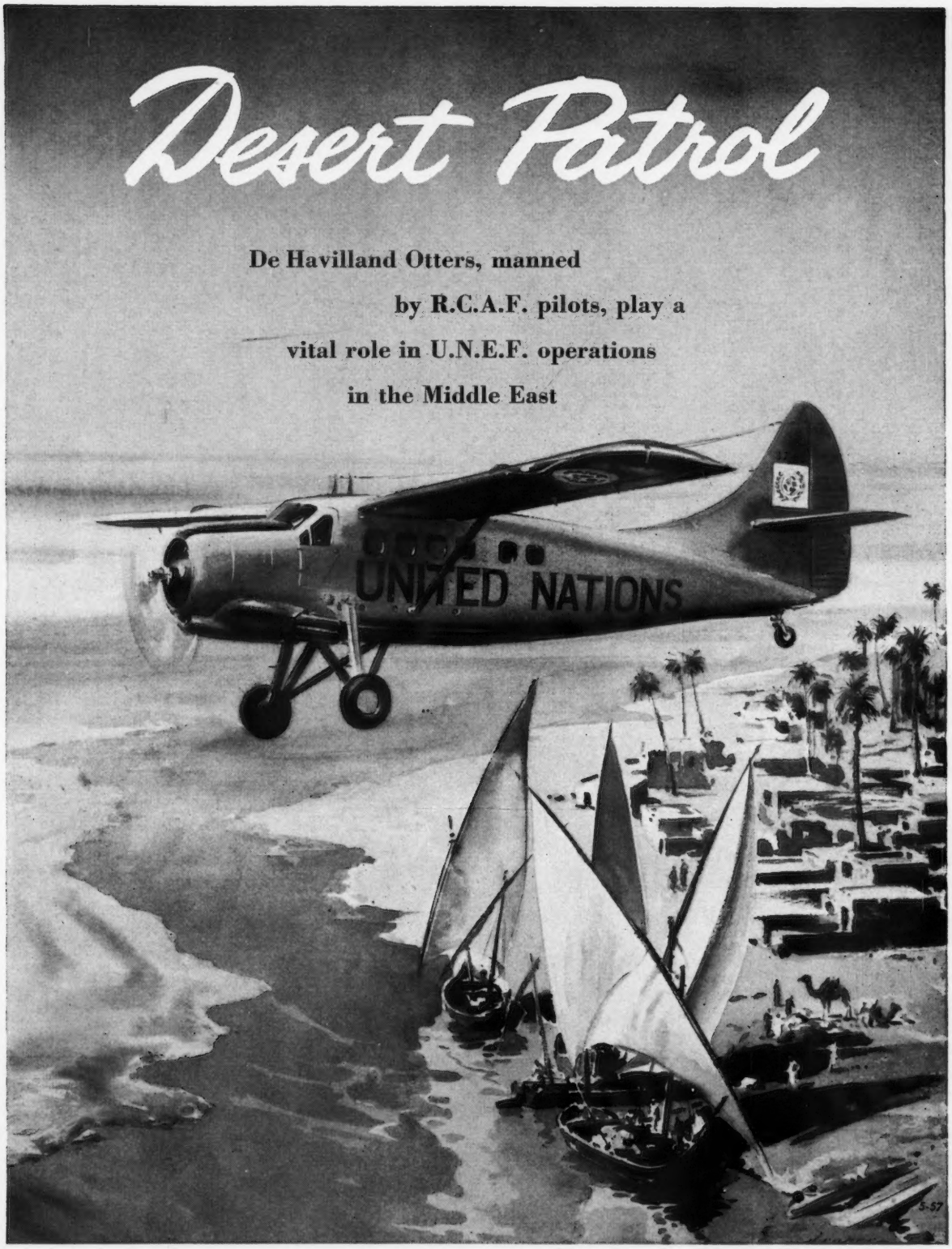

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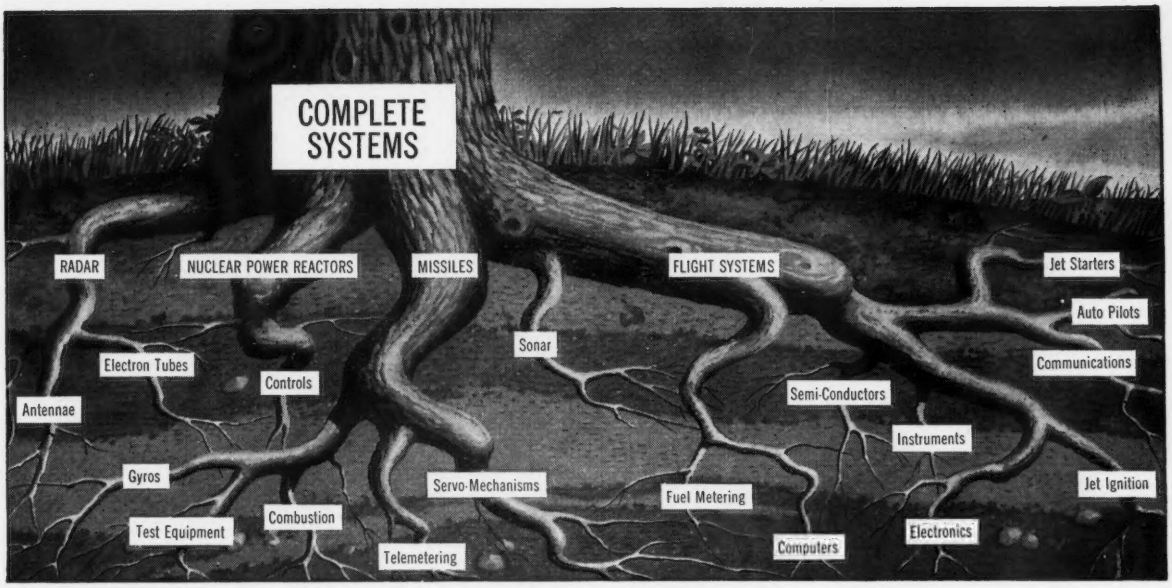

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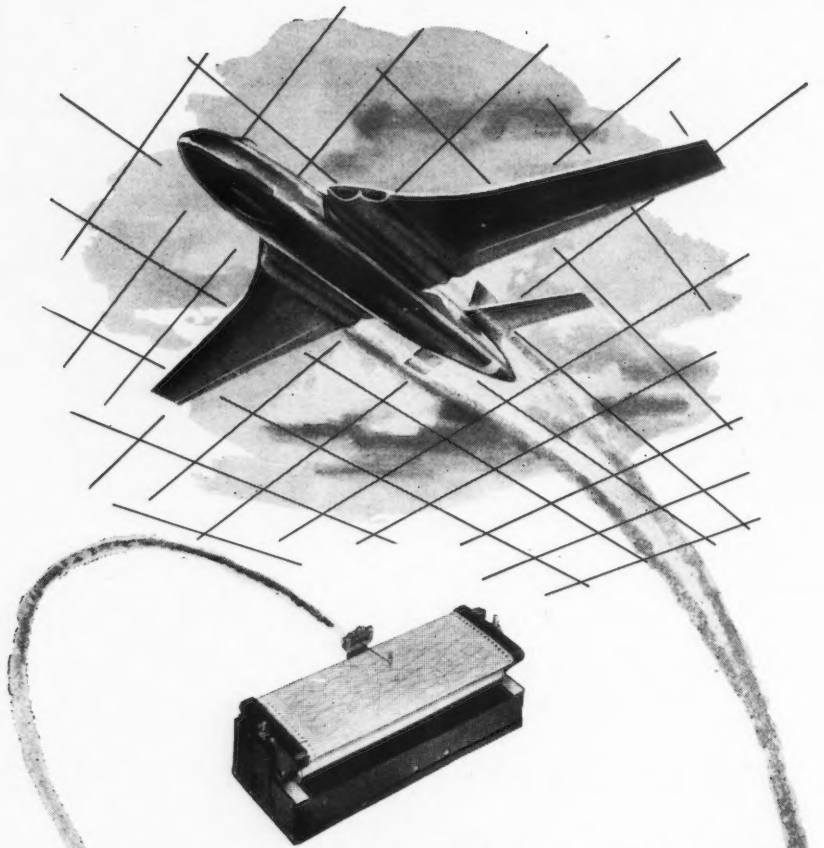

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EDITORIAL

VTOL: WE NEED IT

THE main trend of development of military and civil aircraft has been in the direction of increasing speeds and altitudes. Truly spectacular progress has been achieved as a result of revolutionary advances in power plants, aerodynamics and electronics, accompanied by improvements in materials and manufacturing techniques.

While we fly faster and higher, we require yet larger airfields. In spite of such aids as JATO rockets, propeller and jet reversers and runway barriers, we tend to regress rather than progress in the takeoff and landing requirements. This is perhaps a natural and reasonable state of affairs considering that, with speed the dominant factor, the advantages of air transport are largest when the distances are appreciable. Furthermore, airfields can be relatively easily and cheaply built in developed areas, which attract most of the traffic. With the emphasis on inter-continental bombing and missile defence systems, even the military aspect fits to some extent in this picture.

It is not surprising, therefore, that the ability of aircraft to provide transport where no surface communication exists – its other unique characteristic – remains yet to be explored. Its exploitation critically depends on radical improvement of takeoff and landing performances of otherwise conventional aircraft. With technical advances on the one hand and favourable economic climate on the other, intensive work on the VTOL problems has recently started in the United States, France and Britain.

On the technical side, results of many years of research on different types of boundary layer control suggest ways of achieving high lift coefficients; development of light jet and propeller engines indicates possibility of direct lift; the use of exhaust or compressed air for boundary layer and aerodynamic control and deflection of jet or slipstream for lift are considered. While analysis of various configurations is proceeding, several flying models and piloted "test beds" are being built and tested to solve stability, aerodynamic and mechanical problems.

On the economic side, the need for VTOL performance is acutely felt by relatively thinly populated countries whose natural resources are being vigorously developed. One might mention Canada, Russia and Brazil as the major ones in this category. The helicopter, although already highly perfected, does not satisfy the requirements of range and speed and poses maintenance problems. It seems that superior performance is necessary and pros and cons of VTOL versus STOL have to be examined; for example, STOVL characteristics might be practical for certain missions.

Here in Canada the interest in VTOL is growing among potential users, aircraft industry and government. The panel discussion on high lift at this year's Annual General Meeting and papers presented at the previous Annual General Meeting in Montreal and at the December 1956 Ottawa Branch meeting (see page 185) are indicative of this trend. At the National Aeronautical Establishment in Ottawa performance studies are under way and wind tunnel models are being built. Obviously, VTOL is in its very early stages of development, perhaps as early as conventional aircraft were 40 years ago. But we should realize and make others aware that this country in particular stands to gain most from an early introduction of VTOL into service and that developments towards this goal should be encouraged by all concerned.

STABILITY AND CONTROL PROBLEMS ASSOCIATED WITH SUPERSONIC AIRCRAFT†

by O. E. Michaelsen

*Continued from Page 151**

LATERAL CHARACTERISTICS OF SUPERSONIC AIRCRAFT

Directional Stability and Control

In the past, the required amount of directional stability was dictated mainly by asymmetric power considerations and by the maximum angles of sideslip in manoeuvres permissible from the structural strength viewpoint. Present indications are that the choice of the required degree of directional stability will be based on supersonic lateral dynamic stability considerations and that large values of subsonic directional stability will be required for supersonic aircraft in order to provide satisfactory dynamic characteristics at supersonic speeds at high altitudes.

In order to understand the difficulty in obtaining sufficient directional stability at supersonic speeds, we shall recall that the directional stability of the whole aircraft results mainly from the difference between two large quantities; a positive stability contribution due to the vertical tail surface and a destabilizing contribution from the fuselage. Reference to Figure 1[1] will indicate the large difference between the Spitfire and either one of the two supersonic aircraft shown for comparison with regard to the fuselage length in front of the centre of gravity of the aircraft. The destabilizing moment from the fuselage is much larger for the two supersonic configurations than for the Spitfire. The stabilizing contribution required from the vertical tail is thus very large and a large surface area or a long moment arm must be provided. Practical considerations normally prevent the use of a long moment arm and a large fin area must be resorted to. In order to prevent large supersonic drag penalties and erratic transonic characteristics of the fin, the surface must be thin and elastic distortions due to the aerodynamic loading at high speeds may reduce the fin effectiveness considerably unless large weight penalties are accepted. The variations of fin lift curve slope and centre of pressure position with Mach number are similar to those described previously for a low aspect ratio wing; an increase in the fin effectiveness generally occurs at transonic speeds, but the effectiveness decreases with increasing supersonic Mach number. Since the destabilizing contribution of a slender fuselage is almost independent of speed, the directional stability of the aircraft decreases rapidly with increasing supersonic Mach number as shown in Figure 7.

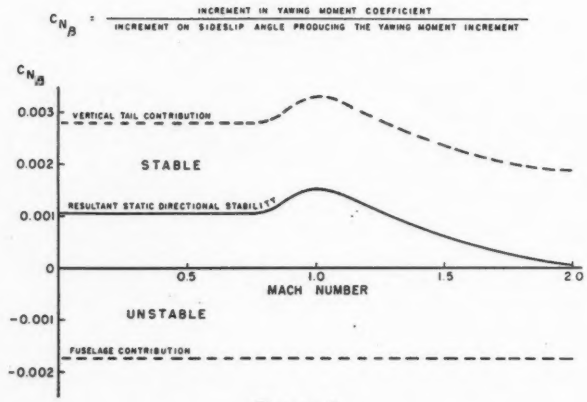

Figure 7
Typical variation of directional static stability with Mach number

The problem of providing sufficient directional stability throughout the entire speed, altitude and angle of attack range without severe drag and weight penalties may present one of the most difficult design tasks for designers of modern aircraft. In fact, it may become impossible to provide sufficient directional stability for operational use at high supersonic speeds and altitudes together with high performance even if the most careful selection is made with regard to wing-fuselage configuration as well as vertical tail size and position. In this case it becomes necessary to resort to autostabilization in order to obtain an operationally useful aircraft. This, in turn, will impose strict requirements on the rudder effectiveness and an all-moving fin might be required.

In addition to the problem of providing sufficient directional stability at supersonic speeds at normal values of incidence, many configurations have shown a large loss of both subsonic and supersonic directional stability with increasing angles of attack. A large reduction of directional stability at large values of incidence may seriously affect the landing characteristics of the aircraft as well as its high speed manoeuvrability and handling. The landing manoeuvre should be possible without artificial stabilization, as an emergency case, and this may prove that once the directional stability is fully satisfactory for landing, it is reasonably sufficient at high speeds and altitudes to make the aircraft safe and artificial stability may only be needed to improve the combat characteristics of the aircraft.

†Condensed from Quarterly Bulletin 1956(3), National Aeronautical Establishment, Ottawa. Received 15th April 1957.
*Canadian Aeronautical Journal, May 1957.

Aileron Control

The requirement of aileron control power for modern high speed, high altitude aircraft may be determined from somewhat different concepts than those used in the past. The damping moment of the wing decreases with decreasing aspect ratio, increasing altitude and increasing supersonic speed. The damping in roll of a typical supersonic aircraft at high speed and altitude may thus be relatively low. Since the rolling moment of inertia of the aircraft is unaffected by speed and height, it is found that once a reasonable rate of roll has been established, considerable time will elapse before the rolling ceases as a result of the low value of damping. If the normal requirements for "roll and stop" manoeuvres are to be met, artificial damping in roll must be provided and powerful ailerons are necessary. The lift effectiveness of the aileron control surface is affected in a similar way to that of the elevator by increasing supersonic Mach numbers and the aileron control power deteriorates almost as rapidly as the elevator pitching moment effectiveness at constant lift with increasing supersonic speed (Figure 5[1]).

Elastic distortions of the wing due to the loads on the deflected ailerons produce spanwise variations in the angle of attack of the wing and hence rolling moments that tend to counteract the moments produced by the ailerons. A considerable loss in aileron power due to aeroelastic effects of the wing may thus occur at high speeds.

Considerable research has been devoted to the development of other means of roll control that compare in power, but avoid the aeroelastic problems of the ailerons at high speeds. Best known of these are variable incidence wing tips and the spoiler control. Variable incidence wing tips give a very powerful rolling moment, but have considerable disadvantages structurally and perhaps otherwise aerodynamically. The spoilers are used to reduce the lift over one wing, thereby creating a rolling moment, and are quite effective at high speeds. Wing twist due to control deflection can be eliminated by proper location and design of the spoilers and a favourable yawing moment is produced by the spoiler drag on the inside wing. Disadvantages of the spoiler system are lack of low speed control response and the reduction of damping in roll at high speeds and altitudes.

It can be shown that in order to meet the manoeuvrability requirements at high Mach numbers and altitudes the lateral control power must be much in excess of what is needed at low speeds and heights. This power is needed first to improve damping through autostabilization, and secondly to provide high enough accelerations in roll. It is possible that some form of pre-programmed lateral control system will be necessary in order to give the pilot the same feel of control at all speeds and altitudes. The programme for the system must be a function of altitude and perhaps also of Mach number.

Lateral Dynamic Stability

For lateral or antisymmetric motion, most aircraft possess three characteristic modes. The first one is known as the roll subsidence mode and is a damped, exponential motion (Figure 6(a)[1]) in which the predominant displacement is in roll. The second lateral mode is an unstable exponential motion (Figure 6(e)[1]) and is referred to as the spiral divergence. This mode can easily be demonstrated in flight by disturbing the aircraft from a trimmed flight condition by a rudder or aileron kick and by watching the ensuing motion. In the usual case, the aircraft will start a slow spiral, in the direction of the disturbance, which will tighten up if uncorrected until a steep high-speed spiral dive develops.

The third lateral mode of motion is known as the Dutch roll oscillation. This oscillation occurs predominantly in sideslip and roll with some yaw superimposed and is similar to the motion of a falling leaf. If an aircraft with a stable dihedral effect suddenly develops sideslip to the starboard, it will roll counter-clockwise and thus tend to produce sideslip to the port which in turn will produce clockwise roll followed again by sideslip to the starboard. For an orthodox aircraft with high directional stability and a moderate dihedral effect this oscillation is normally well damped (Figure 6(b)[1]).

The roll subsidence mode is dominated by the ratio of the aerodynamic damping to the moment of inertia in roll and is not easily recognized in flight at low and medium altitudes since the motion is damped out very rapidly. However, for a supersonic aircraft at high speed and altitude where the damping in roll may become relatively low, this mode may become objectionable from the control point of view in "roll and stop" manoeuvres as mentioned in the previous section.

The spiral divergence mode depends on the relative values of the static directional stability, the dihedral effect, the damping in yaw, and the rolling moment produced by yawing velocity. A supersonic aircraft configuration may be either spirally stable, or unstable, depending on altitude, Mach number, and on the particular configuration. However, generally speaking, this mode does not present any serious problem, because even when instability exists, the divergence of the motion is small. The frequency and damping of the Dutch roll oscillation may vary over quite a wide range for a given aircraft. In addition to all of the characteristic aircraft parameters mentioned above, the Dutch roll is also influenced by the yawing moment produced by rolling velocity and the side force due to sideslip. Since the majority of these parameters vary considerably with angle of attack and Mach number, it is found necessary to investigate individually the stability of the Dutch roll oscillation for each design and configuration under a variety of flight conditions, and it is difficult to give general comments about supersonic aircraft in this regard. A few generalizations can, however, be made.

Firstly, all of the relevant lateral stability parameters are numerically much smaller in the supersonic regime than in the subsonic. The influence of the aircraft inertia parameters thus becomes more important, particularly as the altitude is increased. This generally implies increased periods of oscillation and a considerable loss of damping. Since most of the lateral parameters depend upon the angle of attack, it is necessary to investigate the Dutch roll stability in manoeuvring flight, particularly for supersonic Mach numbers at high altitude. Aircraft which are perfectly stable in level flight may display lateral instability in pull-outs, push-overs or in turns.

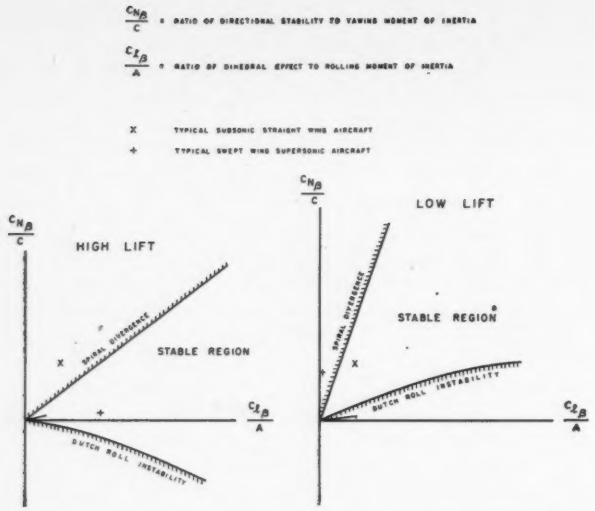
$\frac{C_{N_\beta}}{C}$ = RATIO OF DIRECTIONAL STABILITY TO YAWING MOMENT OF INERTIA
$\frac{C_{\ell_\beta}}{A}$ = RATIO OF DIHEDRAL EFFECT TO ROLLING MOMENT OF INERTIA
X TYPICAL SUBSONIC STRAIGHT WING AIRCRAFT
+ TYPICAL SWEPT WING SUPERSONIC AIRCRAFT
HIGH LIFT
LOW LIFT
STABLE REGION
STABLE REGION
SPIRAL DIVERGENCE
SPIRAL DIVERGENCE
DUTCH ROLL INSTABILITY
DUTCH ROLL INSTABILITY

Figure 8
Typical lateral stability boundaries

Secondly, the importance of maintaining a ratio of directional stability to dihedral effect that corresponds to the ratio of aircraft yawing moment of inertia to rolling moment of inertia cannot be overemphasized. Typical supersonic aircraft, as shown in Figure 1[1], have a large value of the ratio of yawing moment of inertia to rolling moment of inertia. It can be shown that as this ratio is increased, the ratio of directional stability to dihedral effect should increase in order to maintain good characteristics with regard to the Dutch roll oscillation.

The trends of supersonic aircraft configurations are, as pointed out earlier, rather the opposite. Particularly for highly swept-back wing configurations, where the dihedral effect increases and the directional stability generally decreases with increasing angle of attack, considerable difficulty may be experienced in obtaining satisfactory Dutch roll characteristics for any speed at high lift and altitude. The only remedy appears to be a considerable increase in directional stability either by increased vertical tail size or by artificial means.

Figure 8 shows typical stability boundaries for the spiral divergence mode and the Dutch roll oscillation. These boundaries are normally plotted for a particular configuration at various values of lift coefficient and Mach number, and indicate whether or not the values of directional stability and dihedral effect are satisfactory. The location of these boundaries will normally be different for different configurations, but in order to illustrate what has been said above the typical locations for a subsonic, straight wing aircraft and for a supersonic aircraft with a highly swept-back wing have been indicated on the diagrams.

AIRCRAFT STABILITY IN ROLLING FLIGHT

In addition to the conventional modes of motion, a new form of instability can be encountered with supersonic aircraft configurations where the pitching and yawing moments of inertia are much larger than the rolling moment of inertia and where the aerodynamic stiffness terms in pitch and yaw are appreciably different. Inertia forces which tend to swing the fuselage out of the line of flight are set up during rolling, and these forces develop changes in the angles of attack and sideslip. Modern, high-speed aircraft are capable of high angular velocities in roll as a result of high speed and relatively low damping in roll, and the inertia forces and moments resulting from this rapid rotation of the long, heavily loaded fuselage may, under certain conditions, produce disastrous changes in the angles of attack and sideslip.

Before attempting to describe this instability in pitch and yaw during rolling, let us consider the basic stability of the aircraft about the pitch and yaw axes respectively. In the absence of rolling, the static longitudinal stability is defined by the slope of the curve of the pitching moment versus the lift coefficient, or versus the angle of attack, and the static directional stability is defined by the slope of the curve of the yawing moment versus the sideslip angle. If we neglect damping and assume that the aircraft performs small oscillations about the pitch axis, the undamped natural frequency of oscillation is approximately equal to the square root of the ratio of the dimensional static longitudinal stability to the moment of inertia in pitch, that is:

$$\omega_\alpha = \frac{1}{2\pi}\sqrt{\frac{-m_\alpha}{B}} = \frac{1}{2\pi}\sqrt{-\frac{dC_m}{dC_L}C_{L_\alpha}\, q\, S\bar{c}/B} \qquad (2)$$

where ω_α is the undamped pitch frequency in cycles per second;
m_α is the slope of the curve of the pitching moment versus angle of attack in foot-pounds per radian;
B is the moment of inertia in pitch in slug feet^2;
q is the dynamic pressure;
$\frac{dC_m}{dC_L}$ is the static margin;
C_{L_α} is the slope of the curve of the lift coefficient versus angle of attack;
S is the wing area in square feet;
$\bar{c}$ is the mean aerodynamic chord in feet.

Similarly, the undamped natural frequency of pure yaw oscillation is approximately:

$$\omega_\beta = \frac{1}{2\pi}\sqrt{\frac{N_\beta}{C}} = \frac{1}{2\pi}\sqrt{\frac{C_{N_\beta}\, q\, Sb}{C}} \qquad (3)$$

where ω_β is the undamped yaw frequency in cycles per second;
N_β is the slope of the curve of the yawing moment versus sideslip angle in foot-pounds per radian;
C is the moment of inertia in yaw in slug feet^2;
C_{N_β} is the static directional stability.
b is the wing span in feet.

It will be noted that these frequencies increase with speed, but decrease with increasing altitude, increasing moment of inertia, and decreased non-dimensional static stability.

In order to understand the importance of these frequencies in rolling flight, let us consider the roll

history of two fictitious aircraft, the first one having infinite values of pitch and yaw frequencies and the second one having zero values of these frequencies. The first aircraft corresponds to one with infinite static stability about both pitch and yaw axes whereas the other one has zero static stability about these axes. Consider these aircraft flying straight and level without sideslip at some angle of attack. If a rolling moment is applied to the first aircraft, it must roll without changing its angle of attack or angle of sideslip since any such change would cause infinite restoring moments. If the centre of gravity continues to travel in a straight path, a point on the longitudinal axis of the aircraft will rotate about the flight path along a helix, or, following with the aircraft, the longitudinal axis will describe a cone about the flight path axis. If a rolling moment is applied to the aircraft with zero stability, it must roll about the original position of the longitudinal axis since the moment is applied about this axis and since changes in the angles of attack and sideslip fail to produce moments about any other axes. The longitudinal axis thus remains in a fixed position relative to the flight path as the aircraft rolls. The angle of attack varies from its initial value through zero when the aircraft has rolled 90°, to the negative of the initial value of 180° roll, and back through zero at 270° to the initial value as 360° of roll is completed. Similarly, the sideslip angle oscillates between the positive and negative limits of the initial angle of attack as the aircraft rolls, being zero when the aircraft is either upright or inverted.

In the actual case, the resultant axis about which the aircraft rotates will be neither the flight path axis nor the longitudinal axis of the aircraft. A pure rolling moment will attempt to rotate the aircraft about the longitudinal axis, but since a rotation about this axis will produce changes in the angles of attack and sideslip, the static stability moments will rotate the longitudinal axis about the flight path. It is clear that if the rate of roll is very low, the static stability moments will nearly succeed in maintaining the original values of angle of attack and sideslip, that is, the aircraft will rotate closely about the flight path. If the rate of roll is very high, however, the static stability moments have insufficient time to correct the cyclic variations in the angles of attack and sideslip and the aircraft will rotate closely about the longitudinal axis of the aircraft. The aircraft must be considered stable in both cases although the high rate of roll produces steady oscillations in the angles of attack and sideslip.

The time required to correct changes in the angles of attack and sideslip is characterized by the natural undamped frequencies in pitch and yaw of the non-rolling aircraft. It can be shown that if the frequency of the roll is either smaller or larger than the natural frequencies in pitch and yaw, the aircraft will be stable. If the two natural frequencies are both equal to the rolling frequency, a condition of neutral stability exists and any small out-of-trim pitching moment applied to the rolling aircraft at this point will produce a condition of resonance in the absence of damping. When one of the frequencies of the non-rolling aircraft equals the rolling frequency, the aircraft becomes neutrally stable in one mode. This phenomenon may be explained physically on the basis that the restoring forces acting on the non-rolling aircraft which produce a certain oscillation frequency are just offset by the centrifugal forces which attempt to swing the fuselage out of line with the flight path when the aircraft rolls with this frequency. This, in effect, means that the static stability is reduced to zero as a result of the rolling velocity.

It can be shown that when one frequency of the non-rolling aircraft is less than the steady rolling frequency and the other is greater, the rolling aircraft becomes statically unstable in one mode and performs a straight divergence as viewed from the aircraft. This can qualitatively be considered a result of a relatively large rotation of the longitudinal axis of the aircraft about the flight path as a result of the large static stability about the one axis. Inertia moments exceeding the small stability moment in the other direction are thus produced by the centrifugal forces acting on the fuselage and a divergence results.

It will be noted that in the simple considerations made above, no mention has been made of the effect of the mass distributed along the wings. It can readily be shown that the centrifugal forces acting on these masses, when the longitudinal axis rotates about the flight path, will not produce any moments in pitch, but will set up restoring inertia moments in yaw. The critical roll frequency at which the effective static directional stability becomes zero can thus be shown to be increased by the square root of the ratio of the yawing moment of inertia to the difference between the pitching and rolling moments of inertia. A modified directional frequency which is this factor times the undamped natural frequency thus applies during rolling.

The conditions for avoiding serious instability in rolling flight can be summarized as follows:

(a) Both the natural frequency in pitch and the modified directional frequency should be as high as possible and preferably higher than the maximum roll frequency, that is:

$$\frac{\omega_\alpha}{\omega_p} = \frac{1}{p}\sqrt{\frac{-m_\alpha}{B}} > 1 \tag{4}$$

and

$$\frac{\omega_{\beta_o}}{\omega_p} = \frac{1}{p}\sqrt{\frac{N_\beta}{B-A}} > 1 \tag{5}$$

where p is the angular velocity in roll in radians per second;

ω_p is the rolling frequency in cycles per second, $\omega_p = \frac{p}{2\pi}$;

A is the rolling moment of inertia in slug feet^2;

ω_{β_o} is the modified directional frequency, $\omega_{\beta_o} = \omega_\beta \sqrt{\frac{C}{B-A}}$

(b) If the required maximum roll frequency must exceed either the pitch frequency or the modified directional frequency, these two frequencies should be closely

equal so that the possible region of instability is a minimum, that is:

$$\omega_a \approx \omega_{\beta_o}$$

or

$$-\frac{dC_m}{dC_L} \approx C_{N\beta}\frac{1}{1-A/B}\left(\frac{b/\bar{c}}{C_{L\alpha}}\right) \tag{6}$$

In order to demonstrate the design trends which have led to the advent of the divergence in rolling manoeuvres in some present designs, it is useful to re-write Eqs. (4) and (5) in the following form:

$$\frac{\omega_a}{\omega_p} = \frac{0.196}{\left(\frac{pb}{2V}\right)\left(\frac{k_B}{b/2}\right)}\sqrt{\frac{-\frac{dC_m}{dC_L}C_{L\alpha}\sigma\bar{c}}{W/S}} > 1 \tag{4a}$$

and

$$\frac{\omega_{\beta_o}}{\omega_p} = \frac{0.196}{\left(\frac{pb}{2V}\right)\left(\frac{k_B}{b/2}\right)}\sqrt{\frac{C_{N\beta}\sigma b}{W/S(1-A/B)}} > 1 \tag{5a}$$

where $\frac{pb}{2V}$ is the helix angle made by the wing tip during a rolling manoeuvre;

k_B is the radius of gyration in pitch in feet;

W/S is the wing loading in pounds per square foot;

σ is the air density ratio.

The lateral controls for modern fighter aircraft are generally designed to give a certain required value of the wing tip helix angle. Neglecting wing distortion due to aileron deflection, this value is independent of (incompressible) speed and altitude for a given aileron deflection, and the required value of this parameter has not changed appreciably for fighter aircraft in the past 15 years.

Considering, for example, Eq. (5a), it is clear that there are four principal features which combine to lower the critical rate of roll into the range required in normal aircraft handling:

(i) increased radius of gyration in pitch relative to the semispan of the wing $\left(\frac{k_B}{b/2}\right)$. The trend is toward long, slender fuselages with the loads distributed more evenly over the full volume of the fuselage, and simultaneously toward a considerable reduction in wing span;

(ii) increased wing loading.

(iii) increased value of the factor $1-A/B$. Referring to the values given in Figure 1[1], it will be found that this value is 0.25 for the Spitfire and 0.90 for the Starfighter;

(iv) increased operational altitude, that is, decreased value of σ.

It will be noted that the reduction in the critical rate of roll with regard to the pitch axis is not as severe as that occurring in yaw, since the factor $1-A/B$ does not occur here. (The adverse effect due to the reduced value of the lift curve slope resulting from decreased aspect ratio is counteracted by the resulting increase in the mean aerodynamic chord with decreased aspect ratio.)

It is not at all clear how the future designs can be made free from instability during rolling. The "wrong" mass distribution is a consequence of supersonic speed, and is almost outside the designer's control. The obvious cure is to increase the longitudinal and directional static stabilities or bring the frequencies of the longitudinal and directional oscillations as close as possible. The value of the longitudinal static stability is fixed by other considerations, and is already rather high at supersonic speeds. What is needed is an increase of directional static stability to values comparable with the longitudinal static stability. At present, the trend is just the opposite, and the values of static directional stability are small and decreasing with increasing supersonic Mach number (Figure 7). This situation is further aggravated by the fact that the directional stability for supersonic configurations generally decreases with increasing angle of attack. It can be shown that the instability in roll is increasingly violent the larger the initial angle of attack. Directional divergence in a high-speed, high load factor rolling pull-out manoeuvre may thus appear to be the most difficult problem of all.

The difficulty is further complicated by the fact that control movements for recovery from divergence during rolling may be the opposite of what is instinctive and the corrective action may also depend on the initial conditions of the aircraft. It is doubtful if the pilot could "learn" to suppress this kind of instability and the aircraft must therefore be made inherently stable.

Another solution is to put limits on the aircraft rolling manoeuvres. The angle of bank for a fighter aircraft could be limited to 180°, as in practice a pilot never needs more angle of bank, at least not simultaneously with high rate of roll. Limitations of the maximum rate of roll seem feasible provided the rolling time constant of the aircraft is not impaired. Otherwise, the angle of bank reached within a given time would be unacceptably low.

Nevertheless, even if such limitations can be accepted, the aircraft may still have dangerous characteristics within these limitations. In such a case, artificial stability may be the only answer. It has already been pointed out that the basic "natural" aerodynamic stability parameters are too small for high altitude, high Mach number aircraft to provide satisfactory handling qualities; the problem of instability in rolling only strengthens the case for autostabilization about all three axes, especially regarding the static directional stability.

METHODS AND TECHNIQUES FOR THE SOLUTION OF AIRCRAFT STABILITY PROBLEMS

The following section indicates very briefly the methods and techniques used to evaluate the stability and control characteristics of an aircraft. None of the mathematical equations or expressions necessary for the solution of the problems are presented, but an attempt is made to describe the mathematical model which is normally used in these investigations.

Mathematical Representation of the Aircraft

In order to solve analytically any problem in dynamics, it is necessary to formulate the problem in relatively simple mathematical terms. The aircraft is fundamentally considered as a rigid body with a plane

of symmetry moving about in space according to Newton's laws of motion. Since the motion occurs in three dimensions, it is necessary to define one or more systems of axes to which the motion can be referred. The basic system of axes used in stability investigations is one which is assumed to move with the aircraft in the steady motion. Thus, if the steady motion is one in which the aircraft is flying straight and level at constant forward speed, this set of axes has only uniform translation relative to a system fixed in the earth. A second system of axes is fixed in the aircraft and, in the steady motion, coincides with the first set. When the aircraft is disturbed, this second set of axes, which remains fixed in the aircraft, will move relative to the first system of axes which translates along undisturbed. The instantaneous position of the aircraft is defined by the translations and rotations which would be necessary to move from the position of the undisturbed system of axes to the position of the aircraft axes. The rotations must be considered in a specific sequence about the three axes of the undisturbed system. Forces, moments, linear velocities and angular velocities are referred to the aircraft axes system. A set of equations can now be formed which expresses the force balance along, and the moment balance about, the three aircraft axes. In addition, another set of equations must be formulated which relates the translation and rotation of the aircraft system of axes, relative to the undisturbed system, to the linear and angular velocities of the aircraft. Both sets of equations are, in the general case, rather complicated and cannot be handled by analytical methods. The equations expressing the relations between the translations of the aircraft's centre of gravity relative to the origin of the undisturbed axes system and the aircraft's velocity components can, however, be ignored if we assume that the aircraft moves through air of uniform density. By assuming small disturbances from the steady flight condition the remaining equations can be simplified to types that can be handled by standard analytical methods. A further reduction in complexity can be obtained by separation of the longitudinal and lateral degrees of freedom.

Estimation and Collection of Characteristic Values

The set of equations which expresses the force and moment balance relative to the aircraft frame of reference contains expressions that depend upon the mass and aerodynamic characteristics of the aircraft. The mass and moments of inertia of the aircraft can be estimated reasonably easily and accurately from the preliminary design layout of the aircraft, and changes in centre of gravity position, weight and weight distribution are continuously computed throughout the design so that these values are always readily available. The aerodynamic reactions are, however, considerably more difficult to obtain accurately. The static stability and control effectiveness must be estimated during the preliminary design of the aircraft, and the designer must rely upon theoretical and empirical methods, supplemented by test data from similar configurations, for these estimates. The test data will normally comprise data obtained from wind tunnel tests, free flight model tests and actual flight tests of full scale aircraft. Once the preliminary design is completed, wind tunnel models of the proposed aircraft are built and tested and reliable information is obtained with regard to the static stability and control effectiveness of the aircraft. The "dynamic" stability parameters, such as the various damping parameters, and so on, are not easily obtained in a wind tunnel and must be estimated by methods similar to those used in the preliminary design stage for the static stability parameters. The results from the static wind tunnel tests are helpful in these estimates since the effect of some of the components on static stability can be used to estimate their effect on damping. For example, if we know both the location and the magnitude of the side force produced by the vertical tail in sideslip, we can predict reasonably accurately the effect of this component on damping in yaw since rotation of the aircraft about the centre of gravity essentially produces sideslip at the vertical tail.

Dynamic stability parameters can be obtained from free flight, rocket-powered models. This technique produces good results, but is very costly and time-consuming. For supersonic fighter aircraft that may require artificial stabilization, tests of this nature may be mandatory in order to obtain sufficient information to design the artificial stability system.

The estimation of the stability parameters for the actual aircraft may be further elaborated by elastic distortions of the aircraft structure in flight. It is, in this case, necessary to estimate the deflections and distortions of the aerodynamic surfaces under various flight conditions and the effect of these distortions on the stability derivatives. Bending of the wing in a high load factor pull-out will, for example, produce a significant change in the wing dihedral angle, and thus in the dihedral effect, if the wing is thin and flexible.

Methods Used for the Solution of the Equations of Motion

When the mass distribution data and the aerodynamic data for an aircraft have been collected, the values can be substituted in the equations of motion for the various flight cases. The conventional modes of motion can be obtained analytically by solving the equations by methods of operational calculus if the motion is assumed to be limited to small disturbances from the steady flight condition. The longitudinal and lateral stability problems can be investigated separately under these conditions. The longitudinal problem, involving the dynamic balance of forces in the lift and drag directions and the dynamic balance of moments about the pitch axis, is, for example, reduced to that of the solution of three linearized, simultaneous, ordinary differential equations where the independent variable is time and the dependent variables are forward speed, angle of attack and angle of climb. A typical solution of the basic longitudinal modes of motion can thus be obtained if we specify a steady flight condition with regard to aircraft weight, centre of gravity, speed, altitude, load factor and angle of climb. We may consider the elevator angle as a dependent variable which must be specified in some fashion. The motion resulting from a sudden change in elevator angle, a sinusoidal variation in elevator angle, or from a sharp-edged vertical gust can also be obtained analytically without too much difficulty provided the amplitude of the motion is small. The lateral problem can be treated similarly and the response to rudder and aileron step-functions can be obtained.

If the longitudinal and lateral degrees of freedom cannot be separated, or if the amplitude of the motion

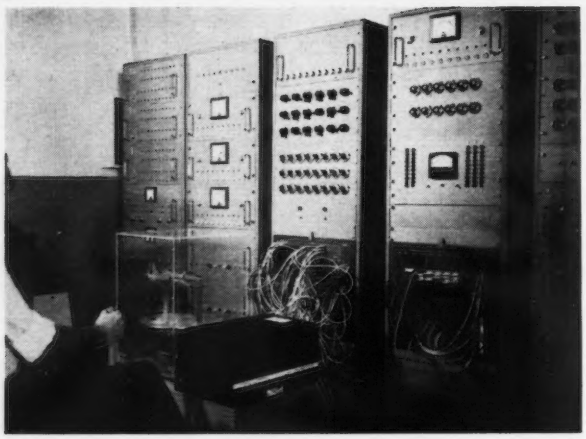

Figure 9

Simple flight simulator set-up on EASE analogue computer using servo-driven model to represent angular displacements

cannot be considered sufficiently small, an analytical solution becomes cumbersome or may not be possible at all. The method almost universally used today for the solution of aircraft stability equations is based on the operational electronic analogue computer. This machine can solve the equations of motion instantaneously once the proper units have been connected together and the proper values of coefficients have been set. These machines are virtually capable of solving the equations of motion for any manoeuvring flight condition, although such elaboration as the variation of the stability parameters with Mach number causes considerable complexity in the set-up. Any investigation directed towards finding the influence on the stability modes caused by variations in the various stability parameters becomes merely a problem of turning a knob on the machine. This type of investigation is important to cover uncertainties in estimation of the stability parameters or possible changes in the design configuration.

The most powerful use of the analogue computer is perhaps the use of the machine as a flight simulator. A simple cockpit mock-up with stick control and rudder pedals controls voltage inputs to the machine simulating the effects of varying control angles. It is thus possible to "fly" the aircraft on the computer and an evaluation of the handling characteristics of the aircraft may be obtained.

A relatively simple set-up of this nature is shown in Figure 9. The particular problem investigated by the Aerodynamic Laboratory in this case was the small amplitude stability of a Canadian aircraft design as affected by coupling between the longitudinal and lateral degrees of freedom due to engine rotor gyroscopic effects. Only five degrees of freedom were used; that is, the Mach number was assumed to remain constant throughout the motion. The servo-driven model simulates the flight angles of the aircraft, whereas the variations in angles of attack and sideslip are indicated by voltmeters on the computer.

The dynamics of the flying control system may be included in the simulation and the behaviour of an artificial stability system can be evaluated. During the design and construction of an aircraft, actual aircraft components, such as the complete cockpit and flying control system, may be connected to the computer and the performance of these components can be evaluated before the aircraft takes off the ground.

There is virtually no limit to the degree of simulation that can be obtained by the use of sophisticated simulation equipment. Special flight simulators intended for pilot training on the ground are being built in large quantities at present. These simulators are "true" in all respects except with regard to inertia forces. The pilot will observe all his instruments and radar as in actual flight, hear the noise from the engines and tires on the runway, feel the pressure and temperature variations in the cockpit, and so on. However, the "feel of the pants" is not present, but neither is the possibility of being killed because of a mistake or failure of the equipment.

REFERENCE

(1) Canadian Aeronautical Journal, pp 146-151, May 1957.

A CANADIAN LOOK AT VTOL TRANSPORT AIRCRAFT†

PART 1

by Squadron Leader E. E. McCullough*

Royal Canadian Air Force

HIGH LIFT DEVELOPMENTS

An area of great aeronautical activity in the past few years has been in the development of devices to improve the lift of conventional aircraft during landing and taking off. An important family of STOL (short takeoff and landing) aircraft has begun to emerge. Furthermore, there is no doubt whatever that the application of high-lift producing schemes will affect future aircraft almost without exception. The great significance of these improvements is that they are not confined to special-purpose aircraft; they can be used to improve slow speed characteristics without imposing a serious penalty on normal flight capabilities.

There is no need to go into the general development aspects of high-lift devices at this time, however, since they have been very thoroughly covered by recent aviation writers and lecturers. The paper presented by Messrs. Irbitis and Phillips at the last Annual General Meeting of the CAI, for example, is an excellent reference. There is, in short, a wealth of information available on both STOL and VTOL (vertical takeoff and landing) development progress. It is not hard to predict what *can* be made available by aircraft manufacturers in, say, ten years' time. The outstanding problem would seem to be: what *should* be made available by that time? It will be of interest to examine the present development situation with this question in mind.

Concerning the development choices available for consideration, it appears reasonable to include VTOL for conventional type aircraft. In the past, the well-known fact that vertical flight for takeoff or landing involves severe power and handling penalties has dampened the enthusiasm of designers who were working toward this goal. As a result, the VTOL concept has always been associated with the idea of a very specialized role, where the penalties involved could be justified. Recently, however, it has become apparent that this line of reasoning no longer necessarily applies. Advances in methods of low-speed control, together with the advent of tremendously powerful turbine engines, have apparently made VTOL flight for conventional type aircraft a more reasonable possibility.

GENERAL REQUIREMENTS

With this background in mind, it is worthwhile to examine the Canadian aeronautical situation, to determine whether the new developments, up to and including VTOL, have any particular application. In other words, the development question referred to earlier becomes: "What transport aircraft development is needed to meet future Canadian needs?" It is proposed now to consider this problem in two parts: in the first, a consideration of Canadian requirements; in the second, a consideration of the developments needed to meet these requirements.

It need hardly be stated that the basic requirement for any development is that the resulting aircraft be competitive when compared with other aircraft or other means of transport. In other words, it must pay a Canadian user, whether civil or military, in terms of profit or military capability to use the aircraft. This profit should not, of course, be derived as a result of a public subsidy, hidden or otherwise. It may be noted in passing that present long takeoff and landing aircraft are subsidized to a major degree in that necessary airfields and other facilities are provided by the community.

CIVIL REQUIREMENTS

As a first step in evaluating the civil requirement, some general considerations of geography and available aviation bases will be useful. Since air facilities are now quite extensive in the populated sections of the country, only the more remote areas of northern Canada need be considered. On the map (Figure 1) have been marked the Northern airfields which are considered to be suitable for use as supply bases. All are capable of handling conventional transport aircraft, and, in addition, some have road, rail, or water route connections. Around each has been drawn a circle to represent an operating radius of 50 nautical miles, which has been taken as the average operating radius of a fully loaded helicopter. The map shows, then, the present VTOL coverage of northern Canada. Finally, arcs have been drawn to represent operating radii of 250 nautical miles from well established bases located in or adjacent to the North.

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*Aircraft Project Officer, Air Force Headquarters.

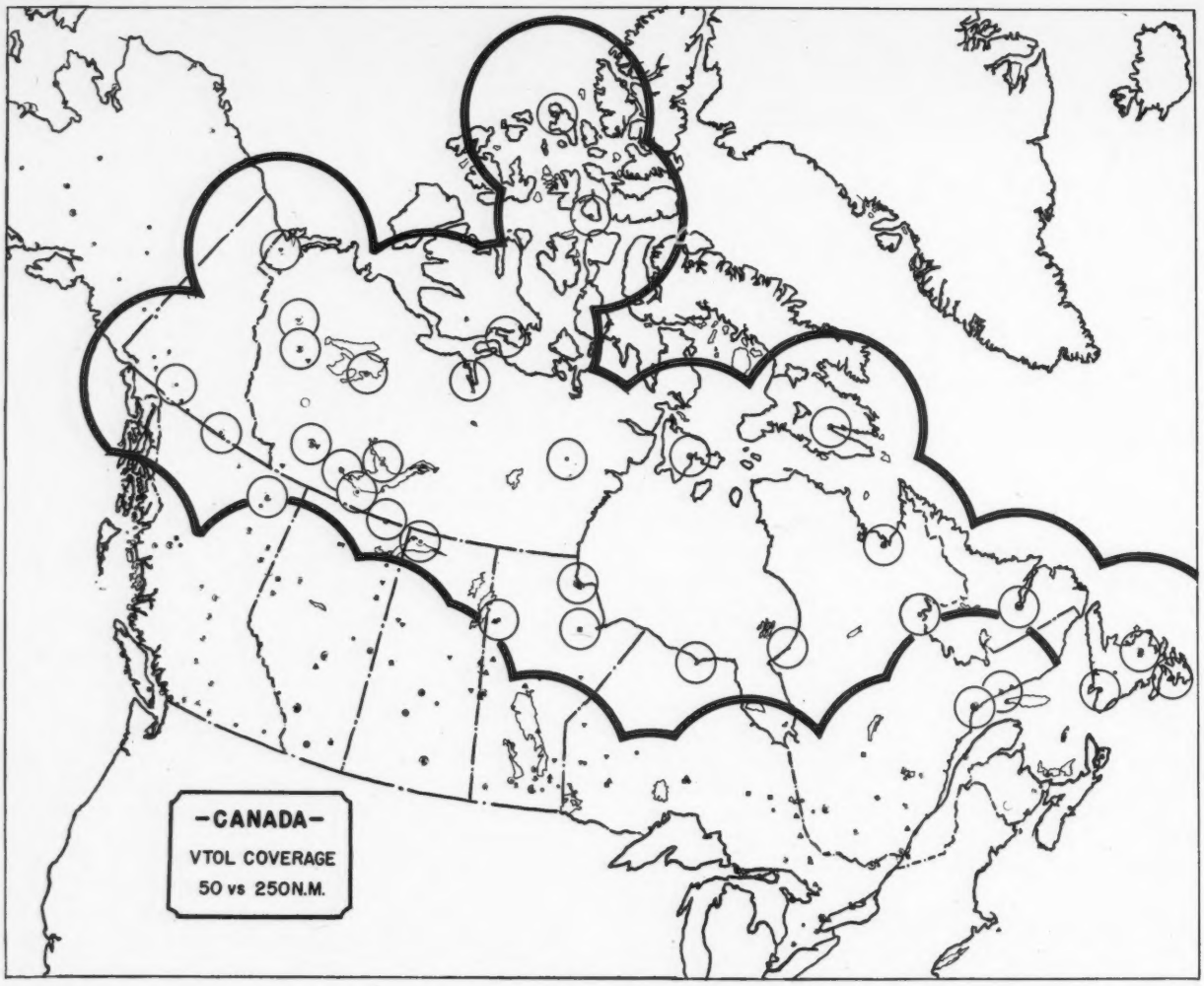


Figure 1
Showing the complete VTOL coverage of Canada that an operating radius of 250 nautical miles will give, as compared with an operating radius of 50 nautical miles.

As would be expected, the present air coverage facilities are not at all good in those parts of the country still under development. It is readily seen, however, that an operating radius of only 250 nautical miles would suffice to put any part of Canada within range of a good supply base. Admittedly, hulls, skis, floats and the bulldozer can make present day aircraft having at least this operating radius usable in the North. The point is that all of these aids either involve an operational penalty or can only be used under very restricted circumstances. Some more generally applicable equipment is needed if the requirements for air transport for Northern development are to be supported from a reasonable number of bases.

It is generally accepted that the development of the North depends primarily on the mining industry. Settlement and secondary industry follow after the initial development of mineral resources. It follows, then, that some easy and economical means of investigating promising mineral leads is needed if progress is to continue to be satisfactory. In the past, Northern areas have been opened up most rapidly around well established transportation routes: the Mackenzie River, the Alaska Highway and the Hudson's Bay railway with their associated developed bands of territory are prime examples. Unfortunately, this pattern has obvious limitations, because major transportation systems can only be set up where geographical features assist, or where some extraordinary need exists. In the latter circumstance, government financial backing is usually required until the system becomes well established. Since it is apparent that only a very limited number of the most promising situations can justify action of this magnitude, some more practical approach to the problem is mandatory.

Consider for a moment the situation facing a company desiring to investigate a particular mineral lead. If the desired location is close to a lake or large stream, small parties with limited equipment can be flown in by float plane. If the location is within 50 miles of a good air base, the party can go in by helicopter. If heavy equipment is needed, such as air compressors, drills, construction materials etc., it must be cut up, flown in and

reassembled, or must be taken in by tractor train during the winter months. The latter means is only available when location and terrain are suitable for limited range surface travel. During the annual autumn freeze and spring thaw, no transportation of any kind is available. These periods may last for several weeks each and cannot be predicted except in general terms.

If the location is not close to a body of water or within range of surface transportation, the situation is even worse. In addition to the equipment needed for the task at hand, equipment will be needed for the construction of runways and roads and for local transport. The difficulty and cost of building even unimproved roads and runways in the rock and muskeg country normally found in our North need no elaboration here. They may, and frequently do, make a whole project unfeasible.

Without going too far into details, it can be seen that the net result is that the whole pace of exploration is slowed down. Only those leads can be investgiated which are close to transportation facilities, or which have obvious evidence of great potential, e.g., the Labrador iron deposits. Other more remote or less obvious situations have to be left until general area development makes them accessible, or until a company with the necessary financial resources decides that the costs involved in an exploration are a justifiable risk.

How much more satisfactory this whole Northern development process would be if an aircraft capable of good range, say 500 miles, and of landing vertically with a reasonable payload, say three tons, were available! The necessary equipment for a particular task could be landed right on site, without the necessity for providing supporting installations which might have to be abandoned after short use. There is no need to enlarge on the subsequent many uses to which the same aircraft type could be put after the initial development stage. The establishment of northern communities would not be tied to the bulldozer as it now is; rather, the bulldozer could be put to its natural use in the consolidation of developments initially established by air.

Other roles in which a VTOL type would fill urgent needs are those of Northern forest fire fighting and of Northern survey operations. Aircraft now available are quite unsuited to operating in the random out-of-way places involved in either fire fighting or surveying.

Turning from the North for a moment, it has been noted that the populated areas of Canada are not too badly served by existing airfield facilities. As air transportation continues to develop as a part of modern living, however, a demand for cheap, short range air transport will arise from the small centers in these areas. The volume of business available will not support large airports or complex facilities, hence the need will have to be filled by aircraft having superior takeoff and landing capabilities over those now in existence. The usual commercial standards of safety and reliability will, of course, be necessary in addition to those improved capabilities.

AIRCRAFT CHARACTERISTICS

Having established a general need for a civil transport aircraft having advanced flight capabilities and which, incidentally, would also have world-wide acceptance, the specific outline of the aircraft should now be determined. It is quite apparent that a rugged, economical aircraft is needed, since it is required mainly in areas where facilities and revenue sources are limited. Mention has been made of the vertical flight capability. The questions can at once be raised "Why will not a more efficient STOL type suffice? Is the vertical capability really justifiable?"

If the two types were unconnected, these questions would be very difficult indeed to answer; possibly the VTOL requirement could only be justified by the existence of an appreciable number of applicable situations, as in the case of the helicopter. Fortunately, the types are not unconnected. A VTOL aircraft can be used in the STOL role, with a consequent large increase in load-carrying capability. On the other hand, an STOL aircraft cannot be used in the VTOL role. In practice, STOVL, that is short takeoff and vertical landing, would probably be most used, particularly in Northern operations. Short field takeoffs would be used from the supply base, followed by vertical landings at the destination.

The flexibility of operation possible with the VTOL type as compared with the STOL type makes consideration of anything but VTOL unrealistic. Properly developed, VTOL aircraft would have all of the advantages of STOL aircraft in addition to the overriding advantage of vertical flight capability. Discussions with a number of Northern air operators have strongly confirmed the deduction that a VTOL capability is essential to handle development tasks with reasonable speed. As noted earlier, the problems involved in moving earth-moving equipment to isolated sites for the purpose of making even short airstrips are tremendous, not to mention the cost involved. A practicable VTOL aircraft would eliminate this problem and others of its kind, and would at once make any point in Canada accessible to air transportation. In short, then, the answer to the question "Is the VTOL capability justifiable?" is a firm "Yes"!

MILITARY REQUIREMENTS

Having established a strong civil requirement for some type of VTOL aircraft, it will be of interest to determine whether a parallel Canadian military requirement exists.

Concerning the Navy it seems that any development to produce short or vertical takeoff and landing capabilities would find immediate acceptance. Shipboard landing facilities are, of course, a prime limiting factor in the consideration of shipborne aircraft. The facilities range from carrier decks equipped with catapult and arrester gear to landing pads on freighters and small warships. The range of aircraft that can be employed follows an equivalent pattern; high performance strike aircraft can operate from the carriers, but only the most restricted operations can be supported from any other ship. Attempts have been made to adapt helicopters to Navy roles, but with only mediocre results. Their restrictions of short range and poor instrument flying capability make them really suitable for little but standby rescue duties. An aircraft having a dual VTOL-STOL capability in all weathers, together with a reasonable range, would at once revolutionize the scope of support type aircraft used by the Navy.

The last few years, particularly since the Korean war, have seen a marked increase in Army awareness of the potential uses of air power for land warfare

applications. In Korea, the helicopter demonstrated conclusively that there was a tremendous need for transport aircraft that could operate right up to the fighting lines. Since that time, Army development of support aircraft has been most vigorous, particularly in the United States. Several most interesting VTOL and STOL types are being sponsored and it is certain that these programs will result in some radically new transport aircraft prototypes within the next very few years. The Canadian Army has not been slow to appreciate the significance of the new trend and plans to investigate close support by aircraft as soon as suitable aircraft are available.

The most probable Army requirements can be visualized as follows: logistical transport support, troop and casualty transport, reconnaissance, and assault transport. Aircraft for such roles would have several things in common: relatively low speed; the ability to operate from rough, unprepared terrain; reliability, ease of operation and maintenance; simplicity and ruggedness. These requirements parallel those previously outlined as necessities for successful civil operations, with the possible exception of the VTOL capability. Let us examine this for application to Army needs.

At first thought, it would seem that an aircraft capable of good STOL performance would suffice. Armies nowadays conduct major operations over reasonably open terrain, where there should be no difficulty in finding level strips of grass or clearing 1,000 or 2,000 ft in length. But what about the situation after a heavy rain? Could the aircraft get in and out then? If so, could surface transport be brought in to the air site? Finally, what about the pilot skill level required to ensure continuous support in all weather conditions? A few questions of this nature suffice to bring out the restriction that conventional type operations involve. And serious restrictions just cannot be allowed in an Army support operation. The war will go on regardless of weather vagaries and the difficulty of finding conveniently located airstrips and, to be effective, the air operation must go on as well. Surely there can be no point in considering STOL if VTOL is available. Granted, the aircraft will undoubtedly be used as STOL carriers most of the time, but the VTOL capability will be indispensable for those situations in which support is most difficult and, hence, most critical. For ideal Army logistical support then, VTOL is a requirement.

Turning to Air Force considerations, it is seen that the situation is somewhat different. Normally, the Air Force must have fairly elaborate bases to handle the high performance aircraft necessary for the various defence roles. In view of this, it does not seem necessary that VTOL, or even advanced STOL aircraft be considered, because of the performance limitations likely to be involved. Exceptions occur, however, as in rescue operations, in isolated base resupply and in Northern defence construction work. In relation to future Air Force defence roles, it is largely held that unmanned fighters or missiles, widely dispersed, will gradually enter the defence scene. Before any effective degree of dispersion and mobility could be achieved under Canadian conditions, however, the VTOL-STOL combination in the associated air support system would seem to be vital.

It may well be that the number of exceptions and the work-load involved would make a VTOL-STOL type of medium transport very attractive to the Air Force. It is certain that aircraft of this type could be put to good use if they were available, even though the Air Force requirements might not justify the setting up of a development project. Regardless of this present need, however, the general future needs of the country as a whole cannot be overlooked; as will be discussed later, the Air Force as a development agency may be capable of providing a valuable service in this area of interest.

Summarizing the argument, there seems to be a strong need for a simple, rugged aircraft of the medium transport category, having VTOL capabilities, for Northern civil operations particularly. This same need exists for Army support. While Navy and Air Force needs seem to be less pressing, the same aircraft type would be most useful to these Services as well.

HELICOPTER APPLICATION

The obvious rejoinder to this proposition is that VTOL helicopters are flying, and are well capable of fulfilling the assignments indicated. As proof, it is noted that a radar line has been pushed through the most remote parts of Canada largely because helicopter transport was available. Helicopters performed yeoman service in the Army support role in Korea and they are performing equally well in present Navy and Air Force roles. These are undeniable facts and everyone must agree that helicopters are here to stay. Nevertheless, other facts are available to prove that helicopters are really only suited to rather specialized operations. Without detracting from their record in true helicopter applications, it is quite easy to show that there is a gap between the operational regime efficiently covered by helicopters and that covered by conventional aircraft.

There is no need to go too deeply into an analysis of helicopter parameters here, because they are well known. It is enough to point out that helicopters are limited by design to low speed, short range, fair weather applications. Furthermore, their inherent mechanical complexity renders them difficult to maintain and costly to operate, as compared with conventional aircraft. As a result, they are limited in civil applications to short haul operations where their ability to hover and to handle an unlimited variety of loads can compensate for the operating costs involved. In military applications, their short range, lack of instrument flying capability, and mechanical complexity make them unsuited for large scale logistical support roles. In short, it seems that the helicopter is compromised by virtue of having been designed for a flight condition lasting only 5% of the normal flight. What is really needed, certainly for Canadian needs, is a machine designed for cruising flight, but having the ability to hover or to fly vertically if required to do so.

SUMMARY

In summary, it can be said that the need for VTOL aircraft has existed for a long time – witness the uses to which helicopters are being put – but that developments in the art and science of aviation are only now making their actual existence a possibility. Now that VTOL aircraft may be feasible, progress in the field of short and medium range air transportation can begin to match that now being made in long-range, high-speed transportation. As a country with a small population in relation to its land area, Canada is eminently suited to take full advantage of aircraft of this type. This will be

a type that can go where the work is to be found, regardless of terrain, weather conditions, population density, prepared facilities etc. It will lead, not follow, development of the more inaccessible areas of the country, as a good transport carrier should.

One further point arising out of this is that Canada has earned a justifiable reputation as a leader in the field of bush aeroplanes. This reputation has only been built up over a long period of years through the foresight, hard work and, let us admit, the acceptance of some risk by Canadians in all phases of aviation from the manufacturer to the user. This reputation is now a matter of national pride and there can be no question of relinquishing it. It only remains, if this is not to happen, for designers and manufacturers (suitably encouraged) to see that the last word in high performance aircraft is made available at the earliest possible time.

On this matter of "encouragement", a few words might be in order. Aircraft of the type discussed, even assuming that they are feasible in all respects, will require long and costly development. Some source of initial support will be necessary until domestic and foreign sales can make the whole project self-supporting. For very obvious reasons, suggestions as to government policies in this matter cannot be made here. Taking everything into consideration, however, the strong Canadian civil and military potentialities of such a development would make it one of more than restricted interest and perhaps one worthy of consideration for some measure of co-operative action.

In Part 2 of this paper, Mr. Pocock will describe the investigations which have been carried out by the National Research Council into the possibility of developing aircraft to fill the various roles just outlined.

PART 2

by P. J. Pocock*

National Research Council

INTRODUCTION

Squadron Leader McCullough has forcefully put the brief before us that there is, implicit in the Canadian air transport scene, a need – a need of long standing – for a VTOL transport aircraft. He has pointed out that such an aircraft would have a uniquely useful role to play in giving expeditious assistance in the important and growing activities in the Canadian northland. Furthermore, he suggests that an initial requirement for such an aircraft might be the ability to carry a payload of 3 tons for a distance of 500 miles.

Now, what will be discussed here are some factors involved in VTOL transport aircraft development and some of the ramifications, in terms of all-up weight, cruising speed, altitude and cents per ton mile of this specification of "3 tons for 500 miles".

TIME-TREND STUDY OF TRANSPORT AIRCRAFT

Everyone no doubt has seen photographs of various projected VTOL transport aircraft in the aeronautical press. One's initial reaction to some of these schemes, aircraft with tilting wings, for example, is sometimes a mixed one and it is mentioned here only because it has a bearing on some of the things I will talk about. One's initial reaction upon seeing these schemes is sometimes this: on the one hand, one is delighted to see an attempt to free the transport aircraft from the takeoff and landing exercise that has been with us from the days of the Wright brothers but, on the other hand, the unorthodox appearance of these aircraft is such that one immediately wonders whether once again here is some strange mutation in the aircraft family that is sure to die of natural causes, if for no other reason than that it takes up a position that is perpendicular to the overall line of transport aircraft development.

It is important to clear this problem up by attempting to see how VTOL transport aircraft look when viewed against the backdrop of the overall time-trends of conventional transport aircraft. As we know, the maximum cruising speeds of transports have been increasing with time. This has been accompanied by an increase in wing loading, which development has led to increasing stalling speeds with a consequent problem of increased demands for runway length. Of immediate interest here is the trend of installed power or thrust relative to all-up

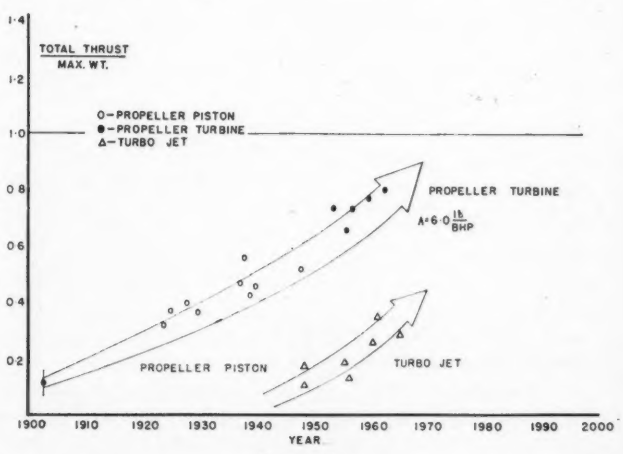


Figure 1

Sea-level thrust/weight ratio—transport aircraft

*Research Engineer.

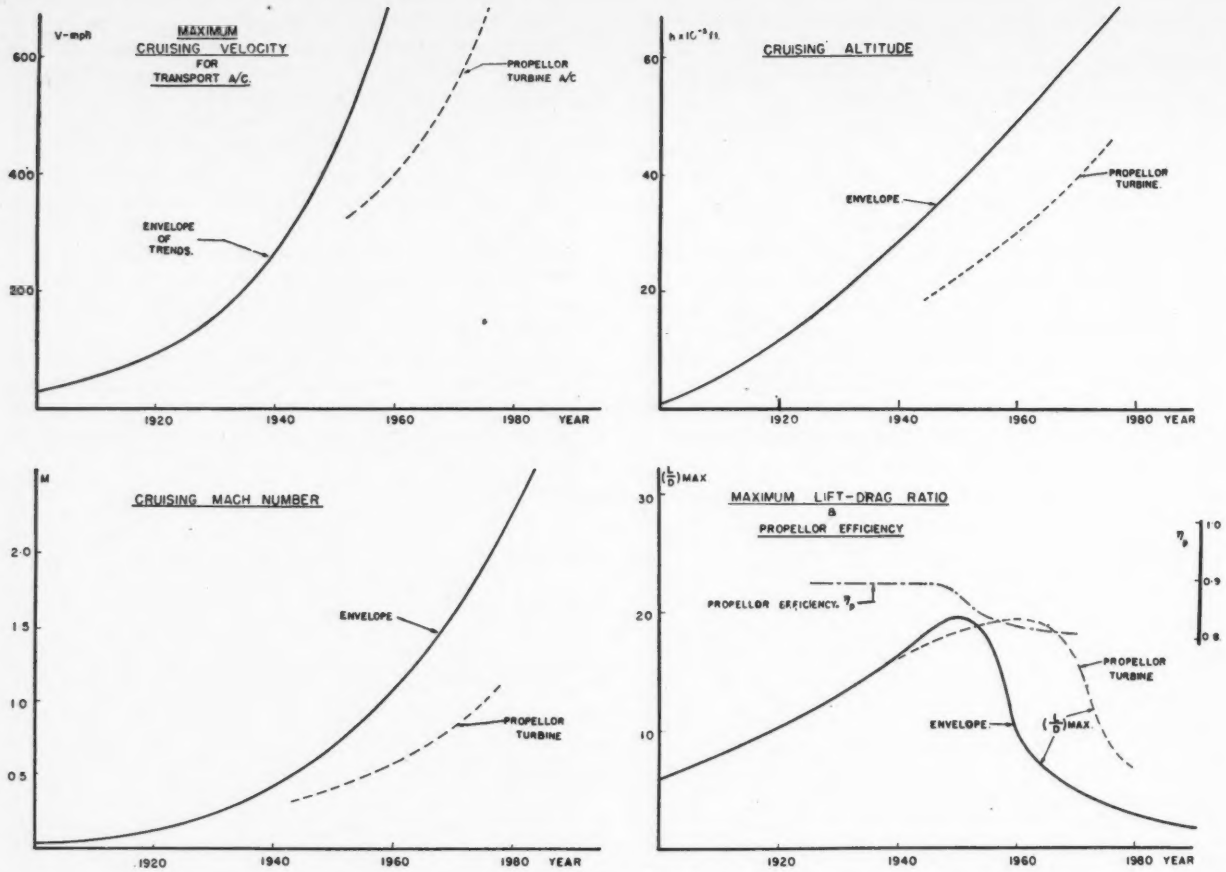


Figure 2
Performance trends

weight, for the reason that if an aircraft is to take off vertically it must have a thrust producing device, which could be its "cruising" power plant, that produces a vertical thrust greater than the weight by a margin considered satisfactory from the point of view of takeoff performance as well as of safety.

The demand for increasing cruising speeds has resulted, for propeller-driven aircraft, for example, in an increase in the ratio of power to all-up weight. Converting this trend into one of sea-level static thrust to weight ratio – the pertinent parameter for assessing potential VTOL capability – involves assuming a value for the thrust producing abilities of the propeller. Assuming a propeller thrust ability of 6 lb of thrust/bhp, the ratio of horsepower to maximum takeoff weight for a large number of conventional propeller-driven transports have been multiplied by 6 to get the static thrust to weight ratio. This figure is chosen arbitrarily, but it does, for example, represent the thrust ability of a conventional propeller that one could obtain for a VTOL transport in the DC-3 weight class. It is assumed that it would be a VTOL transport in this weight class that would be of initial interest.

The results of this process are shown in Figure 1. The ordinate is the ratio of sea-level static thrust to maximum takeoff weight; the abscissa is calendar year. The top curve represents the trend for propeller-driven transports; the open circles are for piston-engined aircraft and the solid circles represent turbopropeller-powered aircraft. The lower curve shows the trend for turbojet transports.

A value of unity for the thrust to weight ratio represents a level of installed power which would just give a potential hovering ability to the aircraft.

Two points emerge from this time-trend study:

(1) The thrust/weight ratios of the propeller-driven aircraft are much greater than those for the turbojet transports. For example, in 1960 the propeller-driven aircraft would require a 25% increase in thrust to have a potential hovering ability, whereas the turbojet transport would need a 230% increase in thrust.

(2) Secondly, the thrust/weight ratios for both classes of aircraft are increasing with time and one is tempted to take a French curve and extrapolate the trends to see at what year a VTOL capability will be reached for each aircraft class. This temptation is resisted and an extrapolation method that can be explained by means of Figure 2 is resorted to.

In the plot in the upper left-hand corner cruising speed is plotted versus calendar year. The solid curve is taken from a study by H. Luskin of Douglas Aircraft and represents the trend of the maximum cruising speed of transport aircraft. At the present time this curve is being followed by the turbojet transports and it is assumed that this will be the case for the foreseeable future. The dashed curve represents the assumed trend for

turbopropeller powered transports. For orientation, some values on this latter curve are:

Year	*Speed*
1960	400 mph
1965	450 mph
1970	550 mph

It is not believed that these predicted values are too optimistic.

The corresponding trend for cruising altitude is plotted in the upper right-hand corner plot and from these two plots the trend of cruising Mach number against calendar year can be directly determined. This has been done and it is plotted in the lower left-hand plot. Some values are as follows:

Year	*Turbojet*	*Turboprop*
1965	1.20	0.69
1970	1.45	0.83

Having thus obtained the cruising Mach number trends, various predictions for the maximum obtainable L/D ratio and propeller efficiency as a function of Mach number are plotted. The maximum L/D ratio goes from a value of 20 for the low subsonic transports to a value of 5 for Mach number 1.5 transports. Propeller efficiency goes from a subsonic value of 90% to a value of 82% at a Mach number of 1.2. These values are considered feasible on the basis of present day propeller research.

It is a simple calculation to convert these data into curves showing the trend of sea-level static thrust to weight ratio for the two classes of aircraft, namely, the turbojet transport, which is setting the pace for cruising speed, and the propeller-driven transport (which we have assumed to be powered by a turboprop power plant). The results of this calculation are shown in Figure 3 where the extrapolated curves are compared with some points carried over from Figure 1.

There are two features worthy of note:

(1) Although an optimistic cruising speed trend for the turbojet transports is assumed, they still enter the area of potential VTOL capability about 10 years later than do the turboprop transports.

(2) The predicted trend-curve for sea-level thrust/weight ratios is quite steep; potential VTOL ability is being approached at a more rapid rate than a "French curve" extrapolation of Figure 1 would suggest.

Some numbers of interest are those for the turboprop aircraft for 1965; this aircraft has a thrust/weight ratio of 1¼. In other words, if it were a four-engined aircraft it would still have close to a potential hovering ability with one engine out. This represents the minimum order of safety factor that one would probably demand of a VTOL transport. The predicted cruising speed of this aircraft is 450 mph.

Having thus predicted a trend for conventional transport aircraft one can stand back and view Canadian VTOL requirements against this backdrop. In doing this, I believe that the situation crystallizes into two important factors:

(1) On the one hand we have before us the suggested Canadian requirement for a VTOL transport. This has been put before us as a definite and important need.

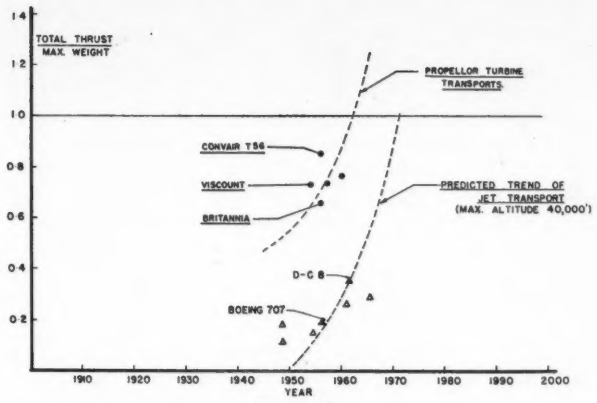


Figure 3
Sea-level thrust/weight ratio—jet transport aircraft

(2) On the other hand a time-trend study of conventional transport aircraft indicates that these aircraft, aircraft in the weight class of initial interest at any rate, will have a substantial VTOL *potential* in terms of sea-level static thrust/weight ratio in the near to foreseeable future.

In view of these two factors I would like to suggest that for any *initial* Canadian VTOL development, effort might be best expended not in the development of special and unorthodox power plants and/or airframes that might appear to have special VTOL features *in themselves* but rather to expend the effort in finding the most practicable way of arranging the standard components of conventional transport aircraft so as to turn the VTOL potential that these aircraft will have into realization, thus meeting the Canadian requirement for such an aircraft. The time-trend study indicates that the turboprop transports will be the first to achieve this VTOL potential and, therefore, this type of transport might be the better one on which to concentrate one's efforts.

Approaching VTOL transports in this manner should not produce some mutative vehicle at right angles to the development trend of transport aircraft. On the contrary, one's activity would be supplementary to this trend.

This is just a suggested point of view that one might take. It does, however, have an advantage that recommends itself. The advantage is this: it simplifies things. By keeping to aircraft whose components and power plants are conventional, and hence fairly well understood, one's limited research and development resources can be left to concentrate in the main on the unknown and hence difficult stability and control problems as well as taking steps to ensure that the operational behaviour of the aircraft is suitable for any special Canadian conditions.

VTOL PROJECT STUDY

Consideration is being given in the Aerodynamics Laboratory of the National Research Council to the stability and control problems associated with VTOL transport aircraft. The steps by which it is hoped to carry this out are two, namely:

(1) To measure the static control and stability of a VTOL model in the low speed wind tunnel, and

(2) Armed with the data from these tests, to investigate the dynamic stability and control behaviour in various flight regimes such as hovering flight and transition from hovering to forward flight by means of an analogue computer.

However, before carrying out these steps one must choose, in some detail, a VTOL transport aircraft. Rather than select a configuration, power plant size etc., at random, the following course was decided upon:

(1) For an initial start the point of view already described was chosen. That is, a turboprop power plant was selected and it was decided that the aircraft should be put together, as much as is possible, with standard components.

(2) Having decided upon a philosophy of approach, an attempt was made to determine what people connected with flying in the northland, for example, considered a minimum useful transport specification. This process led to adopting the following mission requirement:

Payload	2½ tons
Range	500 miles

(3) The next step involved carrying out a project study of a family of VTOL transport aircraft that would meet the basic mission requirement. What was involved here is the following:

(a) An aircraft configuration whereby the VTOL potential could be realized was selected. More about this later.

(b) A range of design cruising speeds from 200 mph to 500 mph was chosen along with a series of design cruising altitudes ranging from sea level to 20,000 ft. For each combination of design cruising speed and altitude the values of propeller disc loading, tip speed and aircraft wing loading that resulted in an aircraft of minimum all-up weight were determined. These aircraft are called "optimum aircraft".

The assumed aircraft mission is for all practical purposes similar to that suggested by Squadron Leader McCullough and therefore it is of interest to discuss some of the results of the project study after describing the configuration selected.

Configuration

Two suggested methods of utilizing the turbopropeller power plant in VTOL transport aircraft are illustrated in Figure 4.

The tilt-wing approach is shown at the top where

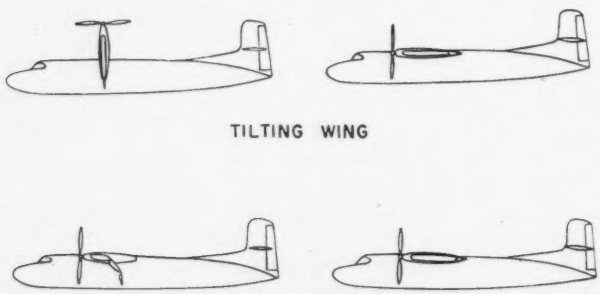


Figure 4
Two types of VTOL aircraft

Figure 5
A Vertol flying test bed

the required vertical lift is obtained by tilting the wing and propeller through 90°. Another trend, the deflected slipstream approach, is shown at the bottom. In the latter, large chord double slotted flaps are used to turn the slipstream through an angle such that the resultant force, when the aircraft is sitting at its ground attitude, is vertical. A combination of these two approaches, a wing with fairly good flap and the ability for partial wing tilting, constitutes another approach.

A flying test bed using the tilt-wing approach is shown in Figure 5. This aircraft is proposed by the Vertol Aircraft Corporation as a flying test bed with which stability and control problems as well as problems of hardware development can be studied.

Figure 6 shows a model of a proposed 60,000 lb tilt-wing transport put forward by the Hiller Helicopter Company. One of the means proposed for obtaining control in hovering for such a configuration is as follows:

(1) Roll control is obtained by changing the propeller pitch.

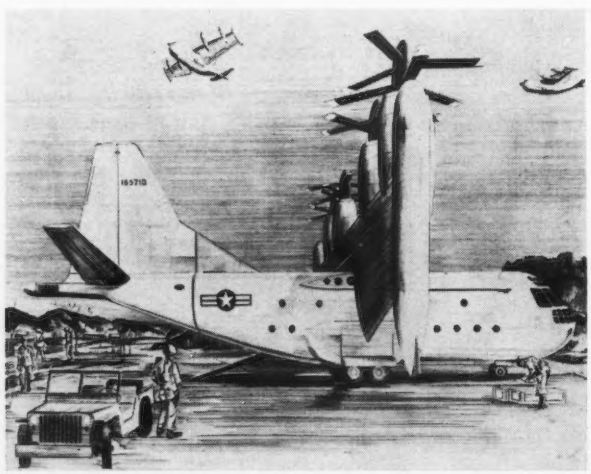


Figure 6
U.S. Army design for a tilt-wing VTOL aircraft

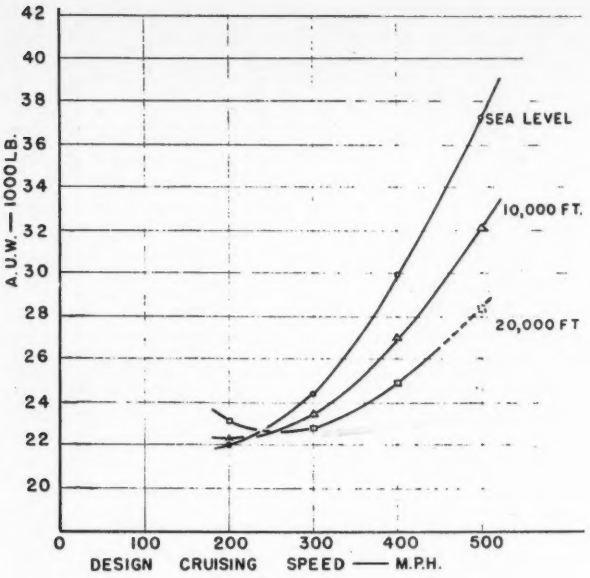


Figure 7
All-up weight for "optimum" aircraft

(2) Yaw control is obtained by working flap-type controls on the wing trailing edge.
(3) Pitch control is obtained by deflecting in an up-and-down direction the jet of a small light weight turbojet engine located in the fuselage rear.

For various reasons the tilt-wing approach was selected for the family of aircraft in the project study.

It was assumed that the aircraft would have four propellers driven by turboprop engines whose specific weight and fuel consumption were representative of what could be expected from production engines around 1965. For reasons of safety it has been assumed in weight estimations that the propellers are interconnected by shafts in order to avoid any asymmetry of propeller thrust due to engine failure. Enough engine power has been installed to allow the aircraft to hover at 6,000 ft at an ambient air temperature of 95°F; this assumption provides ample excess power to enable the aircraft to hover at sea level on a standard day with partial power failure – the loss of one in four engines, for example.

Results of Project Study

These then are some of the main assumptions used in the project study. Figure 7 shows some of the results Here the ordinate is the all-up weight of the "optimum" VTOL transports which are capable of carrying a payload of 2½ tons for 500 miles; the abscissa is design cruising speed. The three curves represent different altitudes : sea-level, 10,000 ft and 20,000 ft.

From these results it is seen that the smallest aircraft for the mission is one having a design cruising speed of 200 to 250 mph; the all-up weight being 22,000 to 23,000 lb. Also, for this design cruising speed, the choice of design altitude has no influence on the aircraft size. If we choose a speed higher than 250 mph, the aircraft size increases and here it pays to fly higher. If one were interested in obtaining a vehicle of minimum initial cost this plot would indicate that the 250 mph cruising speed aircraft would be the candidate. However, there is a catch in this. It is this: the engine horsepower required for

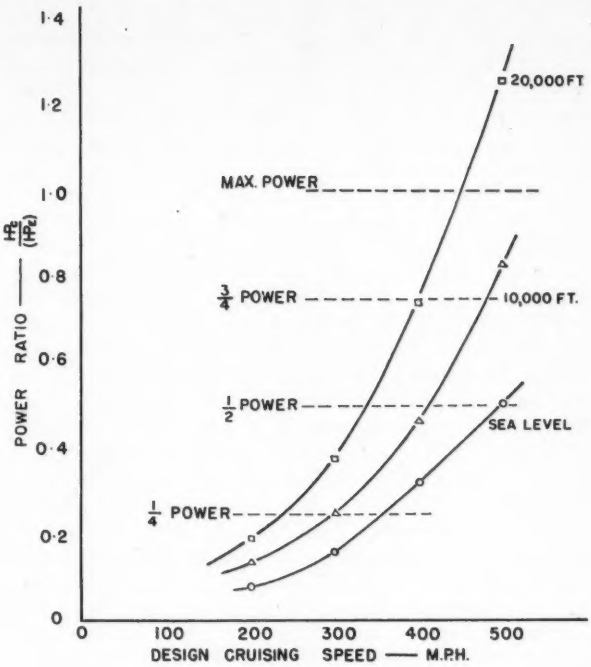


Figure 8
Power ratios for "optimum" aircraft

cruising at the low design speeds is a small fraction of the engine power needed for hovering and therefore, in cruising, the aircraft would be taking most of the engines along for the ride, which might be objected to on operational and/or economic grounds.

Figure 8 shows this situation clearly. The ordinate here is the ratio of the power required for cruising to the power required for hovering, the latter item having included in it the safety margin allowing for partial engine failure. The abscissa is design cruising speed and the three curves represent the three design altitudes that we have considered.

A value of the power ratio of unity means that the installed power required for cruising flight at the selected design cruising speed and altitude is equal to the installed power for vertical takeoff and landing. For our aircraft family we see from this figure that the power demands are matched for a design cruising speed of 450 mph at 20,000 ft. It can be also seen that the choice of a design cruising speed of 250 mph, a speed which we have seen gives the minimum all-up weight, results in a cruising power demand equal or less than one-quarter of the installed horsepower. This would mean that three out of four engines would have to be shut down for the cruise.

Let us look again at the member of our aircraft family whose power levels are matched: the aircraft with a design cruising speed of 450 mph at 20,000 ft.

Some particulars of this aircraft are as follows:

All-up weight = 26,200 lb
Installed horsepower = 9,900 hp (= 2,480 hp per engine for 4 engines)
Aspect ratio ≈ 13
Wing loading = 75 to 80 lb/ft²
Propeller diameter = 14.5 ft

Now the cruising speed of 450 mph is the value taken in the time-trend study as being representative of the cruising speed that conventional transports would attain in 1965. Hence, this particular VTOL aircraft not only meets Squadron Leader McCullough's mission but it has a cruising performance in line with conventional transport development. Actually the main difference between this VTOL aircraft and a conventional fast takeoff and landing aircraft is the fact that the VTOL aircraft is carrying along with it various items of hardware, such as interconnecting shafting and gearing for the propellers, a small jet engine for hovering control and a wing tilting mechanism. From our weight estimations the weight penalty of all this gear is 2,100 lb and, therefore, a conventional transport that has the same cruising speed, cruising altitude, range and all-up weight could carry a payload of 7,100 lb, as compared with the VTOL payload of 5,000 lb. In view of this the *direct* operating cost of our VTOL design, in terms of cents per ton-mile, say, would be higher than that for the conventional transport.

A rough calculation indicates that the direct operating cost of the VTOL transport would be 42 cents per ton-mile and that for the conventional transport, where the VTOL gear has been converted into payload, would be 28 cents per ton-mile. In other words, the direct operating cost of the VTOL transport is approximately 50% higher than that of its conventional brother.

Assuming that the direct operating cost for an airline using these aircraft represents one half of the total operating cost, the cost to the customer shipping his goods on the VTOL aircraft would be 25% higher than if shipped on the conventional transport. The importance of this cost differential can only be assessed in conjunction with a particular cargo-carrying application.

It must be pointed out that the project study figures quoted in this paper are approximate, being based on simple and often crude assumptions. It is intended that they be used to indicate trends and the order of magnitude of the various performance variables.

CONCLUDING REMARKS

All this presupposes that the VTOL aircraft can be made flyable in the hovering and transition regime. More cannot be said about this because at the present time there exists mainly the hope that whatever stability and control problems are found can be mastered. Before this hope can be backed up by engineering judgment a lot of work has to be done, namely, design studies, wind tunnel testing, assessment of the flight dynamic problems on simulators and the testing of small manned test-beds (in that order, say). This represents a series of small steps that would be needed to reach the goal; small steps because, as was pointed out by Mr. Shenstone in his recent CAI talk,[a] in taking small steps you have a higher probability of landing on your feet.

In view of Squadron Leader McCullough's paper I believe that one could say that if this series of small steps were taken with dispatch, energy and imagination they would add up to a big step for aviation in this country.

ACKNOWLEDGMENT

The author wishes to thank the Director of the Mechanical Engineering Division of the National Research Council for permission to publish some of the project study data in the present report. However, the opinions expressed in this paper are not necessarily those of the National Research Council.

The author would further like to acknowledge the great assistance given to him in the preparation of this paper by Mr. A. Bowker and Mr. R. Wickens.

[a]In connection with his paper *Supersonic Passenger-Carrying Aircraft*, CANADIAN AERONAUTICAL JOURNAL, VOL. 3, NO. 1, JANUARY 1957.

I.A.S./C.A.I. MEETING

SHERATON-MOUNT ROYAL HOTEL

MONTREAL

21st and 22nd October 1957

THE SASKATCHEWAN AIR AMBULANCE TECHNICAL AND OTHERWISE†

by D. N. Campbell*

Saskatchewan Air Ambulance Service

INTRODUCTION

On February 2, 1957, the Saskatchewan Air Ambulance Service completed its eleventh year of successful operation. Although many enquiries have been received from interested governments in Canada and the United States, the Saskatchewan Service still remains the only public, organized air ambulance in the world.

Because of its comparative similarity in topographical features to those in Saskatchewan and in particular its scattered population, Australia has faced the problem of providing medical aid through its "flying doctor" service. Basically, the difference between the two services lies in the fact that, in Australia, the physician and medical necessities are flown to the patient and, in Saskatchewan, the patient is flown to the medical centres where specialized medical personnel may best attend to his needs.

The Service operates under the authority of an Air Transport Board license and is designated as a philanthropic air service for the transportation of medical emergencies only. No other type of commercial flying is undertaken.

PERSONNEL AND EQUIPMENT

The Air Ambulance Service has grown from its original complement of one War Assets Norseman, one pilot, one flight nurse and one aircraft engineer, to include six aircraft and 18 personnel of which 4 are pilots and 4 are nurses. The balance of the staff is comprised of 5 licensed engineers (2 "B" categories), 2 mechanics, 1 radio technician, 1 stock clerk and a caretaker. Calls are answered from two bases which are located in Saskatchewan's two major centres, Regina and Saskatoon.

The Norseman

During the first 5 years of operation, several different types of aircraft were experimented with in an effort to settle on the most suitable machine for the task. As mentioned above, the Norseman was first selected due mainly to its availability immediately following the war years and its excellent reputation as a highly versatile aircraft which it gained while in service with various allied air forces. Within a short period it became evident that one aircraft was unable to handle the rapidly increasing number of flight requests and consequently a second Norseman was purchased.

Those first years were trying and hazardous ones inasmuch as the Service had to experiment with several new techniques relative to flying and nursing. With the acquisition of oxygen and completely equipped medical kits, the nurses quickly adopted a standard for attending their patients which, in essence, has remained practically unchanged up to the present time. Flying techniques, however, required a completely new concept of aircraft handling. Calls for emergency transportation were being received from the remotest parts of the Province, miles from any recognized airport or aerodrome, which meant the pilots were compelled to select their own landing areas which were generally small and rolling farm or prairie fields. Rocks, badger holes, old buffalo wallows, cattle, farm machinery and fences only added to the already difficult task of selecting a suitable landing area. One of the biggest problems then and now occurred during the spring "break-up" period. For approximately two weeks in April or May existing snow disappears to the extent that ski equipped aircraft are unable to operate and, at the same time, the spring thaw causes the frost to leave the ground making it impossible to use wheels. In many instances farm land becomes a quagmire which is often next to impossible to discern from the air. In recent years, Air Ambulance pilots have worked out a system to beat this problem (of which more will be said in following paragraphs) but during the period in which the Service was experiencing its "growing pains" the old adage applied of "learn the hard way". As a result fairly serious damage occurred to the Norseman aircraft. Fortunately, no injuries of even a minor nature were experienced by the crew – the patients were not on board.

In view of the obvious tribulations which were involved in operating such a Service successfully, it can be said that the Department of Public Health displayed tremendous foresight in their decision to carry on with the project. Despite the apprehensions of many, the Norseman aircraft were rebuilt and eventually the fleet

†Paper read at the Mid-season Meeting in Winnipeg on the 26th February, 1957.

*Supervisor and Chief Pilot.

was complemented by two Stinson 150's. Over a period of time the Stinsons proved to be impractical, mainly due to their lack of cabin space which added to the nurse's already difficult task of administering to critically ill or injured patients. The Norseman too left much to be desired. In the 40° below temperatures often experienced on the prairies, it became necessary to pile blanket after blanket on the patients in order to keep them in a semblance of comfort. Even with the addition of Janitrol heaters, cabin temperatures differed very little from the outside temperature. Pilots and nurses became chilled to the bone. In the summer, the hot blast from the fire wall (while negligible in the winter) caused pilots to return from a flight wringing wet with perspiration.

The Husky

By this time, the cost of operating the Norseman Pratt & Whitney Wasp Major became a contentious point. Consequently, a Fairchild Husky was purchased. This machine to all intents and purposes was to overcome all previous disadvantages of the Norseman and, in fact, appeared to encompass many additional features which would prove advantageous.

The fuselage was of dural construction and the heating system was more than adequate, thus providing comfort to patient and crew during the winter. The cabin area afforded almost half again as much space as the Norseman. Large doors on both sides combined with the aircraft's close proximity to the ground while at rest made loading a relatively simple task. The Pratt & Whitney Wasp R-985 gave better economy. High lift flaps promised excellent takeoff performance, A JATO rig was installed to further enhance takeoff when necessary. A special integral oxygen system was installed and factory built stretchers proved excellent. In fact, the Husky seemed to have everything required for ambulance work. Catastrophy, however, overtook CF-SAQ on its ferry flight from the factory to Regina. A complete rebuild job was required as a result of a stall following takeoff at Grand Forks, N.D.

Eventually, it was put into service with Air Ambulance and during its three to four years of operation it proved highly effective, carrying 450 patients before being sold. Its faults were few but critical, which precipitated its sale. Cruising speed (especially on skis) was limited to just over 100 mph. The Wasp Junior lacked the necessary power to effectively break the skis loose. It was quite an operation to start the engine, climb out, kick the skis, climb madly back into the airplane and rap the throttle open before it became frozen down again. And, finally, the undercarriage proved to have insufficient strength to withstand the severe pounding imposed on it by rough country terrain.

Saskatchewan Government Photo

Cessna 195

Cessna T50

About this time, an increasing number of flight requests were being received to transport patients to points outside the Province, such as to the Mayo clinic in Rochester, Minnesota. Such trips in the Norseman or Husky were impracticable owing to the slow cruising speed and lack of the multi-engined safety factor under instrument flight conditions. Consequently a war assets heavy wing Cessna T50 was purchased and modified for ambulance work. The wisdom of this purchase was proven within a short time inasmuch as the longer flights could now be completed with a greater degree of safety and speed and pilots' multi-engined instrument ratings could be maintained.

Cessna 195

The search for a suitable aircraft for the in-province rough field operations again became the prime concern and thus the Air Ambulance purchased its first Cessna 195. Like the Husky, the Cessna appeared to have all the requirements including a presumably indestructible steel spring undercarriage. Its R-755 Jacobs promised increased savings in operating costs and yet was able to drag the aircraft through the air at 160 mph. Its long fuselage coupled with the centre of gravity resting well behind the main undercarriage suggested a non nose-heavy tendency, highly beneficial in soft field operations. Demonstration flights (from a hard surface) proved its excellent takeoff and high rate of climb. Initially, the only fault which the airplane presented relative to ambulance work was the restricted cabin area which hindered the nurses while attending to their patients. As usual, however, they modified their techniques to cope with their new problem and, although there are still times when additional space would considerably ease the task of caring for certain types of cases, the overall efficiency was not impaired.

By this time one Norseman had been disposed of and the original one suffered its second turn over and was sold. It was eventually rebuilt and is still flying in northern Saskatchewan.

Over the following three years three more Cessna 195's were purchased which brought the single-engine fleet to a total of four and these remain as the present complement. Inevitably, of course, the Cessna evolved personalized quirks which kept the maintenance staff busy in an effort to win the battle of airplane versus badger holes etc. Rivets were being popped and skins wrinkled in the vicinity of the main gear and fire wall. Tail end bulkheads were being bent and occasionally pulled loose at the shock strut attachment points. Stretchers and aircraft required modifying for easier loading and unloading of patients. The demonstrated

excellent takeoff performance proved not so excellent under certain field conditions and the indestructible undercarriage turned out to be not quite so infallible.

Beechcraft 18

Natural deterioration of main components and the critical lack of de-icing and anti-icing equipment relegated the T-50 to the category of obsolescent. It was replaced with a Beechcraft C18S which was also a wartime product but which, nevertheless, was a considerable improvement over the T-50. After two or three years, it became apparent that a major overhaul on the Beech would become inevitable as various unserviceabilities began to show up which were not merely routine. This fact, in conjunction with its restricted payload (7,850 lb gross), minimum range (no nose tank), lack of propeller anti-icing and obsolete radio equipment, required that a more modern multi-engine aircraft be obtained. Subsequently, after considerable investigation of various types, it was decided that a late model Beech 18 incorporating all the required equipment was the answer. A large influencing factor in settling on the Beechcraft was the standardization of engines and airframes thus reducing the overhead of stock. It was originally intended to dispose of the older Beechcraft but the steady increase in flights completed from the Saskatoon base indicated that, after a complete overhaul, the machine could be utilized efficiently in that area.

The Air Ambulance fleet of aircraft now totalled six (4 Cessna 195's and 2 Beech 18's) which comprise the present complement at this date.

It would be judicious to add at this point that the faults outlined above relative to the various aircraft were not, in fact, faults which would normally be experienced had the aircraft been used for the purpose and under the conditions for which they were originally designed. The problems encountered stemmed almost without exception from the attempts to locate an aircraft which would be ideally suited to air ambulance work under extremely adverse operating conditions. The helicopter was given serious consideration at one time but investigation proved it would be too costly and less efficient in the prairie regions.

PURPOSE OF THE SERVICE

The principal function of the Air Ambulance is to transport emergency patients from remote and isolated farms or small towns to the larger urban centres where required medical attention may be administered. An emergency is generally classed as a patient requiring immediate medical attention or facilities not available at his location and to whom any great loss of time could prove fatal. Other types of patients in a similar category are those who, because of their condition, could not possibly withstand the strain of a lengthy trip in a road ambulance or other surface conveyance but who are sufficiently well to make the time element less important. Requests for flights to the Mayo clinic in Rochester frequently fall into the latter category.

Post-operative bed-ridden patients are flown from the hospitals to their home areas but only when there is no possibility of interfering with emergency calls.

Occasionally blood is flown to a rural physician for administering to a critically ill patient and at various times an urban specialist may be flown to a patient whose need is urgent.

Saskatchewan Government Photo

Beech 18

Calls generally originate from the rural doctor who must also make the necessary arrangements for a hospital bed and receiving doctor at the destination. In cases of obvious urgency, calls are accepted from other responsible persons when there is no local physician available.

COSTS

The cost for in-province transportation of emergency flights has not varied since the time the Service was first begun in 1946 and remains at $25.00 regardless of distance. Besides partially offsetting the cost of the operation, the small fee also serves as a deterrent against possible "frivolous" calls. Experience has proven, however, that non-essential requests have been practically nil and, in any case, can usually be determined beforehand. If the patient does not require a stretcher, nursing attention or special medical equipment, the requesting party is invariably referred to a local charter operator.

Saskatchewan Government Photo

Unloading a stretcher case

Needless to say, the $25.00 charge only accounts for approximately 15% of the cost as the average flight incurs an expense of $180.00 taking into consideration the overall cost of the operation. The remaining 85% is paid from provincial revenues.

For flights outside the boundaries of Saskatchewan or from a hospital to a patient's home the charges are 35 cents per mile. It can be appreciated that the latter charge barely covers the cost of gas and oil. No fee is charged to beneficiaries of public assistance and patients with mental disease or cancer are transported at the expense of the public health agency which finances the total care of those diseases.

The overall cost of the service to the people of Saskatchewan is about 20 cents per capita per year.

PILOTING

From a beginning of 173 patient flights in the first year of operation, the rate has increased and become fairly stable around 800 to 900 flights per year or an average of between 2 to 3 flights per day.

75% of Saskatchewan's population is spread evenly but thinly over the southern half of the Province with a density of only 5 or 6 persons per square mile. Despite the fact that some 160 hospitals are scattered throughout the area, most of which are very small, medical specialists and elaborate medical equipment are concentrated in a few major cities. The pattern of Air Ambulance flights is thus determined by the necessity for utilizing such resources.

Since the first leg of a flight is to a country point a landing must be effected in an unprepared field and therein lies the most serious problem from a piloting standpoint. A routine has been worked out in order to reduce the hazard to an absolute minimum but, even so, the unknown factor remains prevalent. That factor is, of course, the question of suitability of the selected landing area.

There are approximately 85 small airstrips scattered throughout the southern half of the province, most of which have been constructed to aid Air Ambulance operations. The construction project is generally taken on by a local board of trade, municipal council or some other responsible body and is completely financed from local funds. It can be appreciated that the Provincial government could not possibly undertake to provide grants to assist in construction because of the snowballing effect which would result. In other words, every small town would be entitled to the grant which of course would amount to a prohibitive appropriation.

The existing strips are a tremendous aid to Air Ambulance operations, particularly during the spring "break-up" period and throughout the mid-summer crop growing season. They can generally be relied upon to provide a firm landing surface even at times when adjacent farm lands are literally under water as a result of melting snows. The small strip is also greatly appreciated during the summer months when grain crops are in the growing stage. It is an act of complete folly to land in a farmer's half grown crop for two reasons. Firstly, the drag imposed on the aircraft makes it next to impossible to complete a safe takeoff and, secondly, if the takeoff attempt does not wreck the aircraft, the farmer probably will. Our Saskatchewan farmers have proven very unappreciative of the occasional threshing jobs with which Air Ambulance pilots have favoured them. Unfortunately, the usual adjoining summerfallow field does not provide the answer as it seems the farmer insists on cultivating those fields at exactly the same time his crop is growing. Freshly worked land, of course, gives the extra drag which is so highly detrimental to the 195's performance. As previously mentioned, takeoff performance displayed by the Cessna during demonstration periods was excellent but those demonstrations were conducted from a hard surfaced runway. After the machine was put into active service, with landings carried out on everything but hard surfaces, it was learned that unless a semi-lifting speed (approximately 40-50 mph IAS) could be obtained on the initial part of the takeoff the drag on the main gear could not be overcome and the attempt had to be aborted. Occasionally a second try using the original tracks would pay off but always, it seemed, with barely a hair's breadth between the gear and the telephone wires at the upwind end of the field. Periodically it has been necessary to partially deflate the tires in order to achieve a takeoff under such conditions. Excessive amounts of snow or sticky snow offer the same problem when operating the machine on skis. Unlike the Husky and Norseman, the 195 is not fitted with an efficient lift flap and considerable experimentation has proven that, in fact, the use of any degree of the split type flap only serves to delay the takeoff. It is appreciated that the subject of flap benefits relative to takeoff performance is a highly controversial one and invariably evokes discussions about wing contour changes, ground cushioning effect etc. but it will suffice to say at this point that trial and error (fortunately with a minimum of error) has completely eradicated any usefulness of the flap for takeoff.

Needless to say, engine temperatures reach the critical point when prolonged taxiing and/or repeated takeoff attempts are carried out under "heavy" conditions. Generally the pilot's boiling point is reached far in advance of critical engine temperatures and it becomes necessary to shut down for a cooling off period for both man and machine.

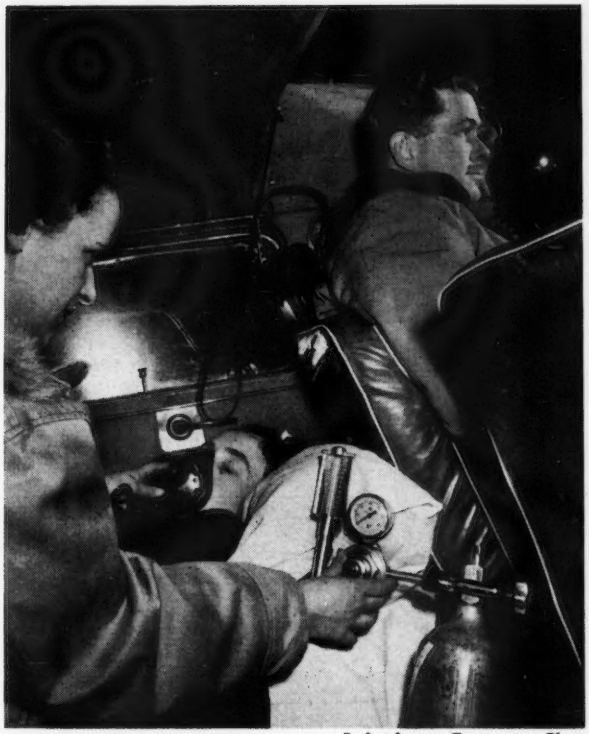
For approximately two weeks every spring practically all types of rural fields become impossible which, as has been mentioned, was the nemesis of the Norseman during the Service's first stage of operation. The small town airstrips, however, invariably drain and dry off in much less time than other surfaces, presumably because of their hard packed condition. During this critical spring period every effort is made by pilots to have the rural doctor transport his patient to one of the strips but about half of the time there is no strip within reasonable distance or else roads are impassable. The procedure then followed is to request that a suitable field ½ mile in length be selected and that a car be driven the full length in a straight line, preferably into the wind, in high gear at 30 mph. If this can be done without the car becoming stuck, then the field is considered safe for an airplane. The requirements seem excessive and, in fact, are but experience has taught that when under the strain of attempting to get a critical patient moved to the city, some lay interpretations of a suitable field often become distorted. On many occasions pilots have been compelled to land on a highway in the vicinity. Infrequently, the

aircraft is forced to return to base without completing a landing. Similar requirements are necessary when conducting a night operation into a rural area but more for the reason of ensuring that a more than satisfactory area exists than would be required for normal daylight operations. If there is any doubt whatsoever, the flight is necessarily delayed until daybreak. Every effort is made to have the patient driven to a licensed airport in preference to carrying out a night landing in the country. Again, however, the problem exists of too few licensed airports. The system which has been worked out to provide the maximum obtainable measure of safety when attempting rural night landings is not complex but is, nevertheless, too lengthy a subject to discuss here.

Another big problem with which Air Ambulance pilots are faced is that of weather extremes. It is probably correct to say that no other flying organization in Canada requests ATC "special" VFR clearances as frequently as does Air Ambulance. The reason is obvious inasmuch as visual contact must be maintained at least for the first half of the flight to a country point. All pilots hold Airline Transport licenses which automatically require a valid Class 1 instrument rating and they consequently are able to and do file an instrument flight plan for the return portion of the flight when necessary. However, if possible, visual contact is maintained on the return half in order to avoid single engine instrument operations. The Service is indebted to the controllers at the air traffic centre in Winnipeg for their cooperation in expediting Air Ambulance flights under adverse weather conditions and consequently the problem is not involved with getting off the ground at the airport. Rather, it is the conflict which the pilot has within himself which is motivated by his desire to render aid to a sick or injured person at some remote location and his experience which dictates when visual flying conditions are no longer possible. The decision as to when a 180 degree turn would be discreet is not an easy one, for as long as visual reference can be maintained there is always the possibility of successfully completing the flight. Again, a system has been worked out which simply involves following a railway track leading to the destination. Contrary to popular belief, the purpose of the railway is not to provide a means of navigation but rather to provide the all important visual reference to the ground. The ever present telegraph poles not only provide this reference but also give the proper perspective relative to level flight without reference to flight instruments. On a dull day under conditions of poor visibility, it would be suicidal to attempt to fly across open stretches of prairie and maintain contact because the cloud and snow covered fields have a habit of blending together – perfect conditions for vertigo. When the telegraph poles begin disappearing, it's time to turn around.

NURSING

It has been mentioned that with the addition of oxygen and complete medical kits the job of the nurse was lightened. In recent years several other pieces of medical equipment have been obtained, all of which have proven invaluable on many occasions. Among those items is the Monaghan respirator which in effect is a portable iron lung. It is impossible to estimate how many lives



Saskatchewan Government Photo

Medical service in cramped quarters

were saved due to the respirator during the polio epidemics of 1952 and 1953. During those two seasons alone, 253 of the most serious polio cases were carried by Air Ambulance. It is probably safe to say that at least 50% of that number urgently required the artificial respiration which was available from the Monaghan. A lightweight incubator, aspirator, resuscitator and other mechanical aids have also been added to the list of available equipment. All electrically driven devices have been adapted to operate directly off the aircraft 12 volt circuit. All equipment is duplicated at the Saskatoon base.

The main problems experienced by the nurses apply to the medical complications with which they are faced. They are constantly forced to make decisions as to what type of treatment they will prescribe for a particular condition utilizing only the equipment and medications which they have on hand. In many instances these decisions would normally be the responsibility of a doctor. The small confines of the aircraft cabin, rough air and slightly diminished air oxygen content all add to the difficulties.

In the eleven years of operation there have been only 13 deaths on board the aircraft out of a total of over 8,500 patients transported.

AIRCRAFT MAINTENANCE

An aircraft was never designed to withstand the treatment to which Air Ambulance machines are necessarily subjected. As a result, the Cessna 195 in its Air Ambulance role resembles the original version only in size and shape. But even the shape has been unexpectedly changed on occasion.

The first modification which was required was to remove the rear passenger seat and make provision for a suitable stretcher. The stretcher had to be wheel equipped with an adjustable head – not merely a temporary arrangement normally provided with the purchase of an aircraft. This meant an entirely new design had to be worked out, mainly because the floor in the rear of the cabin was unavoidably cluttered up with a cabin heater and radio equipment. The arrangement, entailing the fitting of a single wheel to the foot of the stretcher in place of the conventional two wheels, worked well until two aircraft were purchased with Bendix ADF units. The main portion of the units was situated immediately aft of the heater and could not be feasibly positioned in any other place. The single wheel on the stretcher therefore was made retractable. A single seat for the nurse, which had to be readily removable, was installed beside the stretcher.

It seemed that the aircraft was now ready for ambulance service but, after a few landings on the rough prairie, skin wrinkles began showing up on the fuselage immediately behind the fire wall. In fact, the fire wall itself did not prove up to the strain and consequently new skins and reinforcing plates became necessary. The inevitable occurred of course because, as has always been the case, if one section is strengthened the strain shows up at the next weakest point. The wrinkles were chased from the original location to the area around the undercarriage attachment points and from there to immediately forward of the stabilizer. Heavy skins of .051 alclad were introduced to all points and it finally seemed as though an airplane had been achieved which could take it. The satisfied bliss was rudely shattered however when it was discovered that the tail shock strut mountings were cracking and, in fact, were even pulling the rear bulkhead loose. A modification involving additional bridge work at this location practically guaranteed the tail end to remain intact. Again, the belief that a sufficiently rugged aircraft had been obtained was disrupted. The so-called indestructible spring steel undercarriage began snapping at the upper attachment points with uncomfortable regularity. Needless to say, the resultant damage was extensive. Investigation disclosed that the metal was fatiguing at the point of maximum flex and consequently a dye check program was initiated and the legs were inspected after every 100 hours of operation. As time progressed, several cracks were found periodically and the legs were discarded. The original design was replaced by a wasp waist leg which Cessna introduced and which gave promise of longer life. The principle behind the new leg was simply that the flexing action would now be absorbed throughout its entire length instead of almost completely at the attachment point. However, the dye check program was carried on and cracks have been discovered in two of the new type legs to date. One other has broken at the point of axle attachment. It must be said, however, that the latter case has been determined as primarily a result of a flaw in the metal not caused by normal fatigue. Once again it seemed that the Service could breathe easily as far as maintenance problems were concerned. The airframe couldn't possibly come up with any more idiosyncrasies and the Jacobs R-755 engines did an excellent job.

As time went by, however, the occasional accident occurred and the necessary replacement of major components demanded that a fuselage jig be purchased if the aircraft was to be maintained within its original tolerances. For similar reasons a jig for tail surfaces was designed and built by Air Ambulance engineers. The most recent acquisition has been a factory-built wing jig.

Winter operations proved extremely hard on ski bottoms, a new set of skis lasting sometimes for only a week. The cost of continual replacement was of course prohibitive and consequently shoes of 18 gauge black iron were shaped and flush riveted to the bottoms. Like all the other modifications, the black iron shoes have the blessing of the Department of Transport.

The maintenance problem at the Saskatoon base is not one of modifications and major repairs as all such work is carried out at the main base in Regina. The engineer at Saskatoon is responsible mainly for day to day running maintenance which includes progressive 30 hour checks. Unfortunately, however, he works under a considerable handicap inasmuch as the Department of Transport operated hangar is without heat. The business of running an emergency service with the aid of a Herman Nelson aircraft heater during the winter months is, to say the least, problematical.

SAFETY RECORD AND CONCLUSION

The Service has averaged less than one accident per year which is not a particularly ostentatious record except when it is remembered that about half of the landings and takeoffs are conducted from unprepared and thus unpredictable surfaces. While aircraft have been extensively damaged in some of the more severe accidents, the record of injuries to crew or passengers remains 100% perfect. In fact, the patient was on board at the time of the accident on only one occasion. The iodine bottle has remained corked in every instance.

Since the inauguration of the Air Ambulance, advanced medical resources, which at one time were readily accessible to city dwellers only, have become available to the country and small town resident at all times of the year. The problem of moving a critically ill patient no longer exists for, with the services of flight nurses and appropriate medical equipment and supplies, the medical contraindications and physiological hazards are remarkably few. There is no doubt that lives have been saved which would otherwise have been lost.

The cost of operating the service is not low but patients successfully transported and lives saved cannot, of course, be measured in dollars and cents.

One of the biggest problems still to be overcome is the provision of adequate service to the residents of the sparsely settled far north. Northern aircraft operators have been handling the calls to the best of their ability but without proper facilities. Nurses are not carried and medical supplies and equipment are not available. Frequently an aircraft is not available and delays are experienced which could be detrimental to the patient's condition.

Perhaps the greatest value of all is the sense of psychological security enjoyed by the rural population of Saskatchewan who are assured that the Air Ambulance is always available to get them to a distant hospital on short notice.

TECHNICAL FORUM

A SURVEY OF THE ADVANTAGES OF TRANSISTORS IN AIRBORNE ELECTRONIC EQUIPMENT

I BELIEVE that the value of Mr. Johnson's timely paper in the April issue on the present and future impact of transistors on airborne electronic equipment can be enhanced by some clarifications and corrections offered below. These concern particularly reliability aspects of transistors and references to statements of the writer which have been made somewhat misinterpreted in the paper.

In the example given contrasting the power efficiencies of comparable tubes and transistors, it is tacitly inferred that a one-to-one substitution is valid. While in certain transistorized equipment, such as computer circuits, less transistors than tubes may be required, in others[1, 2] tubes have been replaced by two or three transistors. For average airborne equipment, a ratio of 1.25 : 1 transistors/tubes required may be appropriate. The resultant modification of the power saving feature is actually not very significant. Certain transistor circuit designers[2] advocate a more liberal future use of transistors in balancing arrangements and to provide sufficient feedback to overcome the non-uniform characteristics of individual units and variation of these parameters with temperature and time.

To those not familiar with electronic circuit design, it may be misleading to claim that ambient temperatures of 150°C can be endured by silicon transistors which do not suffer the usual 85°C (or 100°C in stabilized circuits[2]) limitation of the earlier germanium types. The limiting factor in practical circuits is the 125°C limit for present types of tantalum electrolytic capacitors required to by-pass many transistor circuits. In an earlier paper[3], previous associates of Mr. Johnson have postulated the use of germanium transistors in airborne equipment (based on attainment of a 95° maximum operating temperature in an ambient of 70°C). This is considered dubious practice for military usage by this commentator and for general use by other conservative designers[2].

It is not questioned that the data presented in the section on "Economic Considerations" regarding weight savings and their equivalents in operating costs are valid for airlines, and weight savings are vital for other reasons in military aircraft. However, an economic factor not discussed is the greater development cost, in the present state of the art, for equipment employing transistors, as well as the greater cost of the parts replacing the tubes. An earlier report[1] quotes the following figures for two equipment conversions:

Equipment	Original Tube Qty.	Quantity of Transistors and Diodes	Costs Tubes	Costs Transistors & Diodes
A	13	64	$ 35	$ 500
B	74	292	200	2,622

Note that this data does not separate the quantities of transistors and associated semi-conductor diodes.

In his section on increased reliability due to substitution of transistors for tubes, Mr. Johnson has misinterpreted the Figure 9 data of his Reference (4) paper by the writer[4]. The number of tubes as a measure of complexity is used as "equivalent tube circuits" and corresponds, for past equipment designs, to a total of component parts including tubes 100/6 greater in number. Thus, in his example, 238 tube circuits correspond to a total of 3,966 parts. If all but 28 tubes are replaced by 400 transistors (a figure supplied privately by Mr. Johnson) and we assume a total of transistors plus other components equal to 8.5 times the number of transistors (instead of a factor of 16.7:1 for tubes), the total number of electronic components (3,866) is not reduced very greatly.

Life data for transistors, except for hearing-aid use, is scanty so far[3, 5] and scarcely warrants the optimistic assumption in the paper of a 100,000 hour life. A recent paper[6] by J. H. Hershey of the Bell Telephone Laboratories indicates a failure rate for transistors 6 times that for crystal diodes and 30 to 65 times those for resistors as a reference component. A more sophisticated analysis is required than that offered by Mr. Johnson from the data in my paper[4] (his Reference (4)). Let us assume a 10:1 reliability improvement for transistors loaded by associated semi-conductors (which Mr. Johnson neglects, and which to date do not have too good a reputation for life) and that 60 per cent of equipment failures are due to the use of tubes. As I have pointed out in the paper's Reference (4), only about one-fifth of these failures claimed are actually due to inadequate design and manufactured quality of tubes and the rest are due to eradicable design misapplications and operating maintenance practices capable of control or circumvention through better human engineering design. However, allowing for the sake of argument the quoted 60 per cent tube responsibility, the net result of substitution of transistors in Mr. Johnson's example would be a reduction in failure rate to 0.463 of the original value.

A more important contribution to reliability from the use of transistors will come from the reductions in ambient temperature possible, provided good packaging and cooling design are employed, and in the reduction of operating voltages, allowing greater safety factors for suitably de-rated component parts. This might contribute a further improvement factor of from 2 to possibly 10:1 and result in an extension up to 200 or 1,000 hours in the mean time to failure of the equipment in the example referred to.

The extended mean time to failure above (200–1,000 hours) is comparable to Mr. Johnson's estimate but his reasoning neglects the factors upon which it is based. He aptly concludes from my referenced data[4] that maintenance practices will probably have a lesser effect on transistor-equipped equipment and that this will lead to further improvements in equipment. However, I must take issue with his assumption from my data that "a large part of the maintenance necessary with electronic equipments is due to the large numbers of vacuum tubes used in their circuits", and his conclusions on the savings in maintenance effort to be credited to transistors. It may also be noted that Figure 6 of my 1956 paper[4] referred to, applies to an average of *all* military equipment and not to airborne equipment alone. Conclusions based on it cannot be projected into new designs including those using transistors involving a different state of the art.

It may be of interest to point out again (as in my recent address to the Ottawa and other C.A.I. Branches)[7] that reductions in size and weight of airborne electronic equipment up to 2 or 3:1 have been effected by good design without the aid of transistors, but using instead soldered-in subminiature tubes. Moreover, it has been reported that overall failure reductions of 100:1 relative to most current designs in use have been effected in military equipment without "transistorization".[8]

In two referenced papers[4,7] the writer has attacked the common prejudice that has been leading some equipment designers and others astray in ineffective remedial measures to improve reliability, namely, that failures and the maintenance effort required to remedy them are predominantly due to tube and other electronic component failures. The vendor who has a "better" component to sell may cherish this naive idea, but the military user and designer cannot afford to be misguided. The Vitro Corporation studies for the U.S. Navy[4] showed that the failures of mechanical and other parts except tubes instead of being negligible, as judged merely from the ratio of number of their failures to total failures, actually accounted for 80 to 90 per cent of the downtime. Without maintenance of airborne equipment in flight, this fact will be less pertinent than in shipborne usage, but it still serves to measure the relative maintenance effort in diagnosis and repair of faults that are more troublesome than those due to tubes which are easier to recognize and correct. Other ARINC studies referred to[4] make it clear that replacement of tubes in military equipment does not result in lowering equipment failures by factors such as 10 or 30:1, as shown for tube failures alone in laboratory or even airline tests, but in a small fraction thereof. Similarly the assumption is not warranted without proof by comparison of actual maintenance experience that the use of transistors having even a 10:1 greater average life than tubes in controlled tests will materially reduce the military equipment failure rate and especially the maintenance effort. Use of better parts and transistors is undoubtedly desirable, but cannot accomplish miracles in improving reliability without more mature equipment and system engineering.

The use of transistors has revolutionized the design of hearing aids and displaced electron tubes in them and in midget personal radio receivers. However, the phenomenal development of new types of transistors every few months, improving thereby ease of circuit design and the frequency range, signal-handling range, inherent noise characteristics, power handling and temperature characteristics of the transistors, arouses a hesitancy towards employing them in military equipment in which it is desired to avoid extreme obsolescence over a five to ten year period. Those interested in considering a similar cautious attitude on the part of the airlines may refer to Poritsky's exposition[9].

The future extensive use of transistors in airborne and other electronic equipment is inevitable and the advantages outlined by Mr. Johnson will probably be exceeded. However, at present, it would be wise not to be oversold on them and fail to consider some of their existing deficiencies and limitations or the difficulties imposed in stable circuit design. Unfortunately, Mr. Johnson's exposition presents none of the difficulties which must be considered in adapting transistors to current electronic equipment designs. Transistors have not yet been proven stable and reliable enough to displace high-quality electron tubes in the trans-Atlantic submarine telephone cable systems in which they are expected to have an average life of 40 years in continuous use.

In concluding this long commentary, may I also enquire whether we must be so economical of language as to endure such horrors as "transistorizable" as well as "transistorization"? Is every new component to be welcomed with new verbs and adjectives and other derivatives as well as legitimate nouns to enrich our overburdened language? As a concession to sales promotion, are we to look forward to "printed-circuitization" and soon to "cryotronizable" etc.?

Ottawa — C. I. Soucy

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(6) Hershey J. H. – *Test to Failure–The Yardstick to Reliability During Design, Manufacture and Use of Military Equipment*, Proc. Joint Military Industry Guided Missile Reliability Symposium, October 15-17, 1956, Redstone Arsenal, Huntsville, Alta. (Unclassified paper in Vol. 2 (Confidential) of Proceedings.)

(7) Soucy, C. I. – *Reliability Control of Electronic Equipment in Aircraft and Weapons Systems: Its General and Management Aspects*, Address presented to Ottawa Branch, Canadian Aeronautical Institute, February 13, 1957.

(8) Bridges, J. M. – *Sound Engineering – The Foundation of Equipment Reliability*, Working Conference on Reliability and Maintenance of Electronic Equipment at the Aberdeen Proving Ground, Md., October 5, 1955.

(9) Poritsky, S. B. – *Airline Approach to Electronic Reliability*, Tele-Tech and Electronic Industries, pp 66-68, May 1956.

THE BIRTH AND EVOLUTION OF THE GAS TURBINE

(The following is an abbreviated version of a long letter received from Dr. Samaras on the 25th January 1957. The original letter contained a wealth of detail, quotations from diaries, memoranda and other records, which must be omitted here.—Sec.)

I RECEIVED lately a number of requests from my former colleagues in the RCAF asking me to make available to you, for publication in the Journal, the necessary information regarding the role played by the RCAF and more generally Canada in the birth and evolution of Jet Propulsion. They brought to my attention an article by V. E. Crompton entitled, "The Birth and Evolution of the Gas Turbine", published in the September 1956 issue of your Journal. It is unfortunate that the author of the above paper is uninformed of the Canadian contributions, especially those of the RCAF.

Conforming to the requests of my RCAF friends, the following historical facts may be mentioned at this time:

Since my attachment (as an RCAF officer) to the NRC Laboratories in June 1941, I tried hard to interest the NRC scientists in Jet Propulsion. Finally at the meeting of the Associate Committee on Aeronautical Research in January 1942, some highlights of my work (1931 to 1941) in Jet Propulsion were reported. At the request of the Committee and of my C.O., A/V/M Alan Ferrier, a part of my work on Afterburning Turbojets, Liquid Injection in the Inlet etc., was published by the NRC as a secret report entitled, "Thermodynamic Performance Considerations of Jet Propulsion" (Report ME-57, February 1942).

Following the above publication, I was interviewed by U.K. representatives, asking more information and details on my work in Jet Propulsion. I was finally sent to the U.K. to help them organize on a more advanced basis the Allied Jet Propulsion effort. I arrived in September 1942 and was sent by the MAP to Rugby with instructions that I combine my ideas with those of W/C F. Whittle. I found that, while my work had been mainly connected with axial flow compressors, W/C Whittle was a proponent of the centrifugal type and held, to my mind, very conservative views on such things as Supersonic compressors, Propeller turbines, Reheat, Heat exchange and Compound engines.

After four hectic months, I was transferred to the RAE Farnborough where the new Jet Propulsion Research organization was being started. During my three year stay, some of my work on Jet Propulsion was published in RAE Reports and annual reports were sent regularly to RCAF HQ, Ottawa.

While I was in England, RCAF HQ in Ottawa did not stay idle. Two technical representatives of NRC arrived in England in 1943 to consult me on the research program and A/V/M Ferrier also visited the RAE. Just before Christmas, 1944, I was called to London to brief A/V/M Stedman, who was on the board of directors of the newly created Turbo-Research Limited regarding the future policies of that company. On my recommendation, the axial flow rather than the centrifugal compressor was adopted. On my return to Canada in 1945, I was posted as scientific consultant to the Chief Engineer of Turbo-Research in Toronto.

In 1946, Turbo-Research was sold to A. V. Roe.

Hoping that the above few selected excerpts from many historical facts and documents in my possession will be appreciated by the Canadian readers regarding the role the RCAF played in the greatest aeronautical revolution of our time.

Fairborn, Ohio — D. G. SAMARAS, PH.D.

LETTER TO THE SECRETARY

I WAS delighted to see Mr. R. B. McIntyre's editorial in the April issue of the Journal. It brought up vivid recollections of the early meetings of the aeronautical section of the E.I.C. in Ottawa. Admittedly, the membership was not so wide as it is now, but we did manage, even with highly technical papers, to get a turnout which represented a very satisfactory percentage of the membership. (TV was not then in public use.)

One of the most remarkable and pleasant features was an unwritten law that the chairman closed discussion not less than one hour before the closing of the beer parlour in the Chateau Laurier and, believe it or not, quite valuable technical discussion took place in the Chateau after adjournment, the point being that the younger men who might be shy about standing up at the formal meeting were less reluctant to ask questions and give opinions in the human atmosphere of the beer parlour. I have no recollection of any discussion that bordered on the offensive in this atmosphere and I am convinced that the older people benefited by hearing the points of view of the younger.

Montreal — A. FERRIER, A/V/M

LETTER TO THE SECRETARY, MONTREAL BRANCH

PLEASE be advised that I am unable to take an active part in our Montreal Branch of the Canadian Aeronautical Institute. I would like to take this opportunity, however, to express my appreciation for the information forwarded to me, in particular, our Journal.

I am a staff member of Canadair's Sales Service Department, helping to look after Canada's technical commitment with the NATO Forces in Turkey. Our group here is a small one so there is no problem in circulating my Journal to all those interested.

The main point I wish to stress with this letter is that I am not silent on the affairs and activities of our organization because of lack of interest but it is due to my geographic location. Later, after my overseas tour has been completed, I will be taking advantage of the many forthcoming meetings.

Eskisehir, Turkey — DAVID D. ROSS

C.A.I. LOG

SECRETARY'S LETTER

ANNUAL GENERAL MEETING

THIS letter is written before the Annual General Meeting has taken place. The Meeting is being held so late in May that we cannot report on it in June and unfortunately the full account of it will have to wait till the next issue, which will appear in September. In fact, not only this letter but the whole C.A.I. Log must be a little 'light' this month, for most Branches have been winding up their season's programmes and there is not much activity to report.

STUDENTS

We recently received a large number of applications from Cadets at the R.M.C. Kingston and before this is printed I expect that most of them will have been admitted as Student members. Of course, they have all scattered to the four winds for the summer and I have no doubt that we shall experience some trouble in keeping in touch with them, although most of them have given us "summer addresses".

This difficulty occurs every year with our Students everywhere. We grope after them through the mails, with a couple of issues of the Journal (May and June) and with occasional notices of Branch meetings; the mail is returned to us and confusion reigns, until we catch up with most of them again when they return to their regular haunts in September. But some of them disappear for good.

I would ask all our members, not only the Students, to remember that we cannot serve them properly unless they keep us fully informed of their changes of address, even for periods of only a month or so.

LAPEL PIN Mk. 2

A new lapel pin has been introduced. It is rather smaller than the old one, consisting only of the old centre, the geese and the maple leaf on the blue field, without the white outer ring, and its finish is considerably better. Its price is still $1.00 and I would point out that we cannot accept old-style pins turned in in exchange.

Personally, much as I like the new pin, I am rather proud of my old one. Someday a "first issue" may become quite a rarity.

FUTURE PROGRAMMES

During the next month or two the Branch Programmes Committees will be busy laying their plans for the fall season and I hope that, when September comes, most of them will have lined up their monthly meetings at least as far as December. It would be a great help to them if individual members would give some thought to the problem and pass on to their respective Branch Committees any suggestions for speakers or plant tours or other technical activities that they would like to see included in the programme.

So far as Institute meetings are concerned, the programme for the I.A.S./C.A.I. Meeting in October is fairly well established but we would like to have suggestions for the Mid-season Meeting next spring or even for additional features, such as special symposia for groups of specialists, which might be fitted into the annual proceedings.

However, the next item on the programme for most of us is a week or two of summer holiday. Enjoy yourselves.

BRANCHES

BRANCH EXECUTIVE COMMITTEES 1957-58

	Chairman	Past Chairman	Vice-Chairman	Secretary	Treasurer	Councillors
Toronto	J. W. Ames	F. H. Keast	W/C E. P. Bridgland	I. F. Rankin	Dr. J. H. T. Wade	S. L. Britton R. B. McIntyre P. B. Dilworth F. M. Hanna
Montreal	E. H. Higgins	T. A. Harvie	W/C C. R. Thompson	W. B. Boggs	K. H. Sullivan	R. J. Conrath A. E. Ades T. A. Harvie
Ottawa	G/C W. P. Gouin	M. S. Kuhring	C. D. Long	P. J. Pocock	W. Symmons	G/C H. R. Foottit J. L. Orr
Vancouver	H. H. Ollis	I. A. Gray	R. J. McWilliams	R. W. Van Horne	A. F. Coutts	A. T. Gilmour R. N. McCollum
Winnipeg	Prof. C. M. Hovey	J. J. Eden	E. L. Bunnell	W. M. Carlson	C. Gross	H. W. Grant W. E. Robinson
Edmonton	S/L J. A. G. Diack	J. G. Portlock	H. Stapleton	C. W. Arnold	C. W. Pearcy	C. C. Young S/L J. E. Moran
Cold Lake	W/C R. D. H. Ellis	S/L R. G. Christie	J. B. Panton	F/L L. S. Lumsdaine	Sgt. B. L. Taylor	D. L. Wallis W/C W. N. Hoye
Halifax-Dartmouth	E. C. Garrard	—	CPO R. L. S. Sabourin	H. S. McCaskill	F/L E. G. MacInnis	CDR (E) E. B. Morris LCDR (P) J. C. Sloan

TRENTON

There seems to be good possibilities of the formation of a Branch at Trenton, Ontario. Such a Branch would cover Peterborough, Cobourg and perhaps Kingston, where there are already a few members of the Institute; and, of course, Trenton itself is a centre of considerable "aeronautical activity".

Flight Sergeant C. R. Holton, recently of the Cold Lake Branch, has offered to serve as "Interim Secretary" and for the time being any enquiries about the proposal should be addressed to him. He will hold stocks of C.A.I. literature and application forms and he will keep in touch with the Secretary of the Institute on any local developments. F/S Holton's address is

GRU Machine Shop,
6 Repair Depot,
Trenton, Ontario.

NEWS

Ottawa

Student Section March Meeting

Reported by F/C D. H. Allatt

On Thursday, March 28, cadets of the Royal Military College of Canada, with interest in things aeronautical, met to form a Student Section in Kingston. The stimulus for such an organization at the College had come from several of the cadets who had been members of the Student Section at Royal Roads and found that in Kingston they were isolated from the Institute's activities in the larger cities. Fortunately, S/L C. J. Evans of the Mechanical Engineering Department at R.M.C. is a member of the C.A.I. so that there was no difficulty in finding a senior representative to sponsor the cadets. Upon enquiry, it was found that there were some 50 other cadets interested in forming a Student Section.

The meeting of the 28th March was arranged by S/L Evans with the idea that the cadets might have an opportunity to ask questions about the C.A.I. and, having satisfied themselves, a Committee might be set up to commence plans for the College year beginning in September. The cadets were very fortunate in having the Secretary-Treasurer of the C.A.I., Mr. H. C. Luttman, attend the meeting. He had been very active in helping the cadets at Royal Roads set up their Section and the problems at Royal Roads were not too dissimilar from those which faced the R.M.C. cadets. If a Section were established at R.M.C., there were two major problems which had to be overcome; firstly, finding time to hold meetings and, secondly, arranging an affiliation with one of the Branches, either Ottawa or Toronto. Mr. Luttman pointed out that although the Toronto Branch already had a Student Section and would, therefore, seem the logical affiliation, Ottawa was somewhat closer and it was thought that it would probably prove better that the Ottawa Branch should be the parent Branch for the Student Section at Kingston.

S/L Evans suggested that the Student Section at Kingston should not be made up wholly of R.M.C. cadets but should include students from Queen's University. Although size is not a criterion in in the Section's success, a larger group would provide a better field for the selection and presentation of technical papers.

A Committee was elected, consisting of a representative from each of the four year's cadets with a Chairman and a Secretary elected from the third year cadets, as follows:

Chairman–M. D. Thom
Secretary–F. G. Forrington
Year Representatives
4th W. N. Russell
3rd D. H. Allatt
2nd D. F. Moffatt
1st P. J. Ashley

With the coming of exams to R.M.C., it was inevitable that the Committee restrict itself merely to organizing those cadets who had expressed a desire to join a Student Section. It is hoped, however, that the Section will be able to meet during the period between the end of the exams on the 26th April and Graduation on the 17th May.

April Meeting

Reported by S/L W. M. McLeish

The April meeting of the Ottawa Branch was held on Wednesday, 17th April, and consisted of a plant visit to Computing Devices of Canada Limited, Bell's Corners, on the outskirts of Ottawa.

The attendance was excellent and approximately 135 members and guests were entertained by CDC, who handled the overflow crowd without a hitch. Prior to the official CDC welcome, the Branch Secretary advised the members of the results of the election for the 1957-58 Branch Executive.

Some of the Ottawa Branch members at CDC looking at the ANTAC System

Mr. J. S. Parsons, Technical Director of CDC, welcomed the guests and briefed them on the Company's organization, technical ability and future plans of aeronautical interest. Mr. J. E. Smith, Manager of the Technical Services Branch, was then introduced and he provided a running commentary on a film of some of the Velvet Glove trials for which CDC supplied a data processing service.

The audience was then divided into five groups, provided with escorts and shown around the Data Processing Centre, Instrumentation Department and Semiconductor Engineering Department. The digital and analog computers attracted a great deal of interest since for many of the members it was their first glimpse of these examples of electronic wizardry.

The ANTAC navigation system demonstration was quite timely since it forms the backbone of the Canadian Argus which recently made its initial flight. The demonstration was quite realistic since it was performed on a special test panel designed by CDC for initial calibration and testing of the system by Canadair on all production aircraft.

The Semiconductor Department discussed techniques in miniaturization of electronic components through the use of transistors and had an excellent display of the miniatures as well as some of their component build-ups.

The evening was terminated in the pleasant atmosphere of the CDC cafeteria where coffee and sandwiches were served. S/L G. B. Waterman thanked CDC on behalf of the C.A.I. and expressed very admirably the feelings of the members that CDC be complimented on its cooperation and support of the Ottawa Branch.

Montreal

Reported by W/C C. R. Thompson

April Meeting

"Cockpit Automation", a philosophical discussion of the modern trend of automation in controls as this applies to aircraft and associated equipment, was the topic of a talk to the Montreal Branch on the 17th April by Mr. O. S. Davidge, Engineering Department Head for Electro Mechanical Development at Sperry Gyroscope of Canada, Montreal.

Mr. Davidge was introduced by Mr. H. A. Ross, the Vice-Chairman of the Branch.

The discussion of automation gave a general definition of it, as it affects operation of aircraft, as the mechanical performance of control operations, including the sensing and measurement, data processing, computation, actuation and error measurement, pertinent to the proper utilization of the aircraft in its intended role, in a manner analagous in general to that performed by the human operator.

After a brief review of the history of the growth of aircraft automation in general terms, the speaker then showed that, for some operations, an operator alone was more desirable; for others, automatic presentation of data, leaving the decision and action to the operator was a better solution; but for some, the solution and action is automatic and independent of the operator who may then only monitor. He pointed out that for aircraft the choice of these alternatives must be based on judgment of all the factors involved but it is most necessary to design the aircraft as an integrated efficient whole. In summation, originally visual data was presented to the pilot, using him as the computer and servo system. More recently semi and fully automatic sub-systems have relieved the pilot of some of his burden. In the future, this can be extended as far as we choose and probably relieve the pilots of nearly all of their functions except that of exercising professional judgment.

The speaker was thanked by Mr. H. Halton. Questions after the talk covered such points as whether it was better to concentrate on keeping the major part of the complicated calculating equipment on the ground or in the aircraft; whether automation by a system of flight cards was possible; whether an automated flight plan system is desirable. The concensus of the meeting was that no amount of automation would or should eliminate the stewardess from airline aircraft.

Cold Lake

Reported by R. W. Ellard

April Meeting

The April meeting of the Cold Lake Branch took place on Wednesday, April 17th, in the Library of the Sergeants' Mess.

W/C R. D. H. Ellis opened the meeting and introduced the guest speaker, Mr. J. Graham of Canadian Pratt & Whitney Aircraft Company Ltd.

Mr. Graham, who had chosen "Rotating Wing Aircraft" as his subject, gave a brief history of the helicopter, with special reference to the North American continent. He went on to describe how the helicopter flies and its method of control. Mr. Graham gave illustrations of the economics of helicopter operations and described some of the operations which were particularly suited to the helicopter.

A film, entitled "3 if by Air" by Sikorsky Aircraft Ltd., was then shown.

Mr. H. D. Procter-Gregg thanked the speaker. Refreshments were served and a question period and general discussion followed until 11 pm when the meeting was adjourned.

Thirty members and guests attended this meeting.

May Meeting

The Annual General Meeting of the Cold Lake Branch took place on Tues-

day, May 7th, in the Library of the Sergeants' Mess.

S/L R. G. Christie opened the meeting and presented the Annual Report.

The meeting was then turned over to the new Chairman, W/C R. D. H. Ellis, who stressed the need for an intensive membership drive in his inaugural address.

Halifax-Dartmouth

April Meeting

Reported by H. S. McCaskill

The fifth meeting and first Annual Meeting of the Halifax-Dartmouth Branch of the Institute was held in the Lounge of the CPOs' Mess, HMCS Shearwater, on the evening of the 24th April. Attendance consisted of a total of thirty-eight members, prospective members and guests.

The initial business portion of the meeting was concluded by the report of the election of officers for the 1957-58 season presented by Professor O. Cochkanoff who, with Mr. C. Wearing, acted as scrutineer.

It was particularly appropriate that Mr. H. C. Luttman, Secretary of the Institute, was able to be present at the meeting. Asked by the Chairman to say a few words, Mr. Luttman discussed some of the finer points of Institute Regulations regarding admissions, duties of Councillors and development of new Branches. He expressed considerable pleasure in seeing the formation of the Halifax-Dartmouth Branch inasmuch as it completed the chain of Branches from coast to coast in Canada.

The guest speaker of the evening, Mr. M. C. Eames of Naval Research Establishment, Dartmouth, completely held the interest of the meeting with his presentation of "Some Problems of Hydrofoil Design".

Tracing the Hydrofoil project from the basic requirement, namely that of a stable, high speed and manoeuverable craft, capable of operating in seas of up to 6 ft height, the speaker used slides to show the various types of hydrofoils developed. Of particular interest to the Branch, Mr. Eames pointed out that much of the preliminary work in the hydrofoil field had been carried out by F. W. "Casey" Baldwin and Alexander Graham Bell in Nova Scotia.

Mr. Eames dealt with the subject of cavitation effect as being comparable to aerodynamic turbulence and mentioned methods of incidence-area control and foil incidence.

A feature of the talk was the discussion of some of the unusual stresses involved in the construction of a craft of this type. The speaker explained, with a minimum of formulae, some of the weight/area/speed problems involved.

As a truly impressive "training aid", the speaker circulated a cross-section of the foil. He explained that the foil, with a chord of 7½ inches and a submerged span of 6 ft at top speed, served to keep a 6,000 lb craft "airborne".

At the conclusion of Mr. Eames talk, the business meeting was reopened in order that CPO R. L. S. Sabourin, Vice-Chairman of the Interim Executive Committee, could present the Annual Report. Reading of the interim Financial Report by Professor O. Cochkanoff concluded the meeting.

MEMBERS

NEWS

Dr. E. P. Warner, Hon.F.C.A.I., was awarded a Doctor of Laws degree, honoris causa, by McGill University at the spring convocation in May.

Rt. Hon. C. D. Howe, Hon.F.C.A.I., received an Honorary Doctorate of Science degree from McGill University at the spring convocation in May.

S. P. Johnston, Hon.F.C.A.I., has been elected a Fellow of the Royal Aeronautical Society.

I. M. Hamer, F.C.A.I., has been elected a Fellow of the Royal Architectural Society.

R. Farmer, A.F.C.A.I., formerly with Canadair Ltd., has accepted a post as Engineer Designer with Boeing Airplane Co., Seattle.

W. H. D. Hanchet, A.F.C.A.I., has left Doman-Fleet Helicopters to take up a position with Canadair Ltd.

A. E. Larratt, A.F.C.A.I., has recently accepted an appointment as Chief of Structural Design with The Kaman Aircraft Corporation, having left his position with Canadair Ltd.

A. S. Jackson, M.C.A.I., has left TransAir Ltd. to take up a position as DEW Line Operations Manager with Wheeler Airlines, Montreal.

I. Millett, M.C.A.I., formerly with Orenda Engines Ltd., has taken up an appointment as Customer Engineer in the Transport Division of the Boeing Airplane Co., Seattle.

D. W. Pounder, M.C.A.I., who has been on loan to C.A.R.D.E., has returned to the De Havilland Aircraft of Canada to join the Engineering Dept.

J. N. Dykshoorn, Technical Member, formerly with Jarry Hydraulics, has taken up a position with Boeing Airplane Co., Seattle.

R. H. Yenney, Technical Member, has left the National Aeronautical Establishment to join the Aerodynamics Section of De Havilland Aircraft of Canada.

DEATH

It was with deep regret that we learned of the death of **A. G. Clarke, M.C.A.I.,** who was Supervisor of Instrument Design, Orenda Engines Ltd.

SUSTAINING MEMBERS

NEW SUSTAINING MEMBER

THE following Company has joined the Institute as a Sustaining Member:

Canadian Westinghouse Company Ltd.

NEWS

Canadian Car Company Ltd. announces that it has obtained the Canadian manufacturing rights for the Beech T-73 primary jet trainer.

Canadian Pacific Air Lines Ltd. has ordered another Britannia 310 series increasing their Britannia fleet to six, with an option on another five. The aircraft will be used on the CPAL routes to Japan, Australia, South America and Amsterdam.

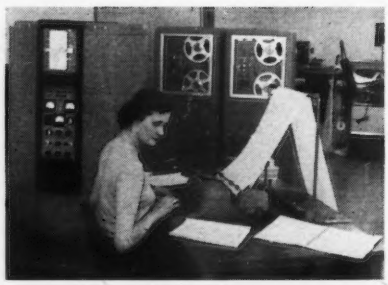
ElectroData Division of Burroughs Adding Machine of Canada Ltd. has established a data processing educational programme on the Datatron sysetm. The programme is designed to give prospective users an opportunity to evaluate the equipment as well as to provide current users with additional training in operation and coding techniques. It includes a five-day Basic Datatron Programming Course and a two-day Executive Evaluation Conference and it is made available in Toronto, Montreal and Ottawa, three times in each city during the current year.

Computing Devices of Canada Ltd. have recently acquired a new digital computer, a Bendix G-15D, for use in their Data Processing Centre.

As an example of the use of this computer in handling turbine design problems, which frequently require a great deal of repetitive solution of thermodynamic equations, CDC cites a case involving computation of the specific nozzle area, output and fuel consumption of a gas turbine, based on turbine design data and free stream conditions.

In this case, 729 sets of answers were required to take into consideration all of the combinations of the given parameters and constants. In obtaining these solutions, the entire process of computation was repeated for every combination.

Cost of manual methods, assuming engineering time at from $7.00 to $10.00 an hour, including overhead, would have been about $25,000. Cost using a G-15 computer was about $225.00. The problem was solved in 17 hours as against an estimated 2,916 hours by manual methods.



Information being fed by means of an electric typewriter into the new Bendix G-15D digital computer at Computing Devices of Canada.

This turbine data analysis problem is a conspicuous though not uncommon example of results obtainable through the use of a general purpose digital computer such as the G-15D. Any problem that would require one-half day of manual computation or would be used 12 or more times, can be considered as a possible application.

In addition to time and cost savings, considerable upgrading of the degree of accuracy is gained and results are held to a consistent level of completeness and precision. A photograph of the computer is shown above.

Honeywell Controls Ltd. has announced a completely new line of precision switches designed for use in aircraft rocket and similar applications.

These are the first switches successfully to resist the highly corrosive effects of many rocket propulsion gases. Designated the 21AS Series, these switches consist of a high-capacity switch attached to a rugged, cam-type actuator which will withstand heavy impact or hammer-type blows on the actuator. The complete assembly is small, compact, environment-proof and will resist normal adverse conditions found in exposed locations of high-speed, high-altitude aircraft.

The basic switching unit used in the 21AS1 is a qualified product under Military Standards MS24331 and the 21AS2 is designed to conform to the same standards. Contact arrangements for the 21AS1 are a 2-circuit double-throw; the 21AS2 has a single-pole single-throw. Electrical rating for the 21AS Series is given in Table 1.

TABLE 1

28 volts dc — sea level*

	21AS1**	21AS2
Inrush	24 amps	24 amps
Resistive	4 amps	4 amps
Inductive	3 amps	3 amps
Motor	4 amps	3 amps

20 volts dc — 100,000 ft*

	21AS1**	21AS2
Inrush	24 amps	24 amps
Resistive	4 amps	4 amps
Inductive	2 amps	2 amps
Motor	4 amps	3 amps

*Electrical ratings established with tests on unsealed switches.

**The basic switching unit in this switch assembly meets immersion test requirements of MIL-E-5273A Procedure 1.

Although the 21AS Series of switches has been designed specifically for use on aircraft rockets, it may be successfully used wherever a rugged, sealed, small switch is required for an indicating or lookout switch.

LETTERHEAD EMBLEMS

Sustaining Members are reminded that half-inch diameter cuts of the C.A.I. emblem, as above, may be obtained without charge on application to the Secretary.

SUSTAINING MEMBERS

of the

CANADIAN AERONAUTICAL INSTITUTE

1957-58

Aeroquip (Canada) Limited

Aircraft Industries of Canada Limited

Alloy Metal Sales Limited

Aviation Electric Limited

Avro Aircraft Limited

Babb Company (Canada) Limited

Bristol Aero Engines Limited

Bristol Aero Engines (Western) Limited

Bristol Aeroplane Company of Canada (1956) Limited

Bristol Aircraft (Western) Limited

B. W. Deane & Company

Campbellford Precision Products Limited

Canadair Limited

Canadian Car Company Limited

Canadian Pacific Air Lines Limited

Canadian Pratt & Whitney Aircraft Company Limited

Canadian Steel Improvement Limited

Canadian Westinghouse Company Limited

Cannon Electric Canada Limited

Carriere and MacFeeters Limited

Collins Radio Company of Canada Limited

Computing Devices of Canada Limited

Decca Navigator (Canada) Limited

Decca Radar (Canada) Limited

DeHavilland Aircraft of Canada Limited

D. Napier & Son Limited

Dorval Metalcraft Company

Dowty Equipment of Canada Limited

ElectroData Division of Burroughs Adding Machine of Canada Limited

Enamel & Heating Products Limited

Fairey Aviation Company of Canada Limited

Field Aviation Company Limited

Garrett Manufacturing Corporation of Canada Limited

General Controls Co. (Canadian) Limited

Godfrey Engineering Company Limited

Goodyear Tire & Rubber Company of Canada Limited

Honeywell Controls Limited

Imperial Oil Limited

Jarry Hydraulics

Jet Ignition Company

Lucas-Rotax Limited

McMillan Industrial Corporation

Moffats Limited (Avco of Canada)

Normalair (Canada) Limited

Northwest Industries Limited

Okanagan Helicopters Limited

Orenda Engines Limited

Prenco Progress & Engineering Corporation Limited

PSC Applied Research Limited

Railway & Power Engineering Corporation Limited

Rolls-Royce of Canada Limited

Rousseau Controls Limited

Shell Oil Company of Canada Limited

Simmonds Aerocessories of Canada Limited

S. Smith & Sons (Canada) Limited

Spartan Air Services Limited

Standard Aero Engine Limited

Thompson Products Limited

Trans-Canada Air Lines

Walter Kidde & Company Limited

York Gears Limited

The Flight Research Section
of the
National Research Council
located at
Uplands Airport, Ottawa, Ontario,
has the following vacancies for
qualified engineers:

AERODYNAMICS ENGINEERS
To assist with researches on aerodynamic problems. The selected applicants will be expected to participate in planning and conducting research projects, some of which will require experiments in flight. The work will be varied and interesting and will appeal to those who prefer to work in a small group closely associated with aircraft. It will in turn require an ability to originate ideas in both the experimental and theoretical fields.

Candidates should have completed a post graduate course in Aeronautical Engineering (Ph.D., Masters Degree or its equivalent). Alternatively candidates from other courses, such as Engineering Physics, but with a strong interest in and familiarity with aeronautical subjects will be considered.

MECHANICAL ENGINEER
To assist with researches on aeronautical problems. The selected applicant will be expected to participate in planning and conducting research projects, some of which will require experiments in flight. The position requires an ability to design experimental equipment for airframes and power plants. Familiarity with turbine engines is desirable.

Candidates should have completed a post graduate course in Aeronautical or Mechanical Engineering (Masters Degree or its equivalent). Alternatively candidates with a Bachelors Degree, but with pertinent supporting experience, will be considered.

INSTRUMENTATION ENGINEER
To work on the design of instrumentation systems and on the design and development of special instruments for flight research purposes.

Applicants should have a university degree in Electrical Engineering or Engineering Physics.

All salaries commensurate with education and experience. Letters of application or requests for further information should be sent to the Employment Officer, National Research Council, Sussex Drive, Ottawa 2, Canada.

Instrumentation Engineer

HIGH SPEED LABORATORY
DEFENCE RESEARCH BOARD
OTTAWA, ONTARIO

The Defence Research Board requires an engineer to take charge of design and development of special instrumentation, controls and data handling systems to be used in high speed wind tunnels. Applicants must be familiar with applications of strain gauges and other transducers, automatic electronic controls, analogue and digital data handling systems etc. Should also have wide experience of instrumentation equipment currently available in Canada and the U.S.A. This work calls for an imaginative and original approach to a large variety of advanced instrumentation, control and data handling problems.

Candidates must be Canadian citizens or British subjects and graduates of a recognized university in electrical engineering or engineering physics (or the equivalent) with a good academic standing and must have several years of pertinent experience.

Initial salary is dependent on qualifications and experience.

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Please refer to 57-DRB-5 15/5/57

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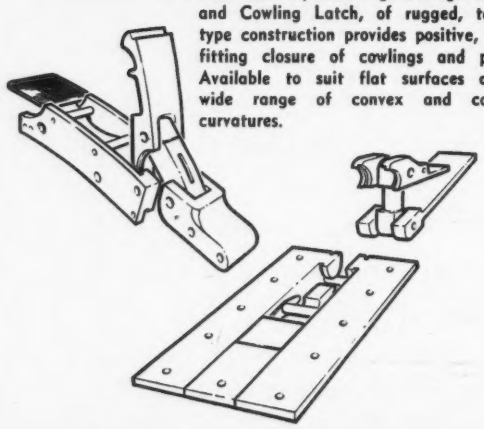

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Part view of the machine shop at the Toronto plant of Lucas-Rotax

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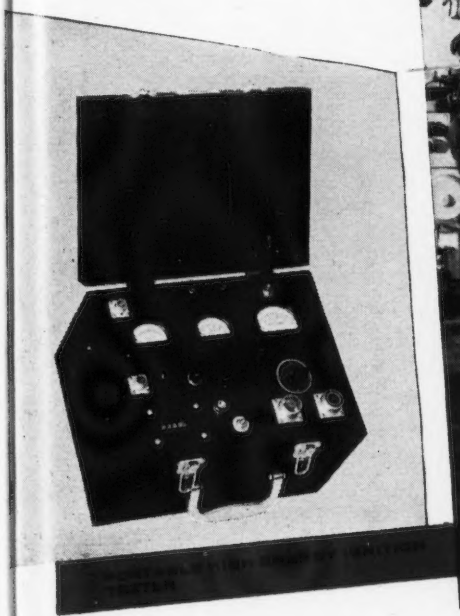

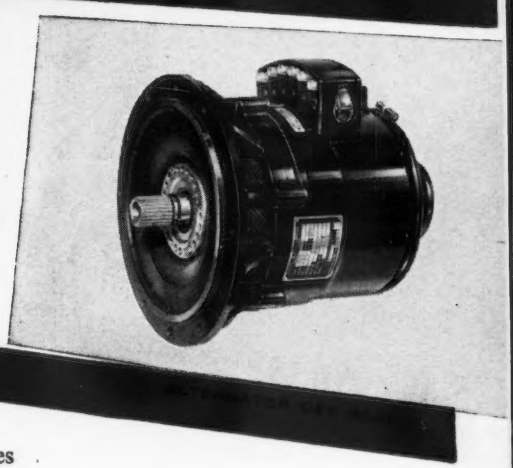

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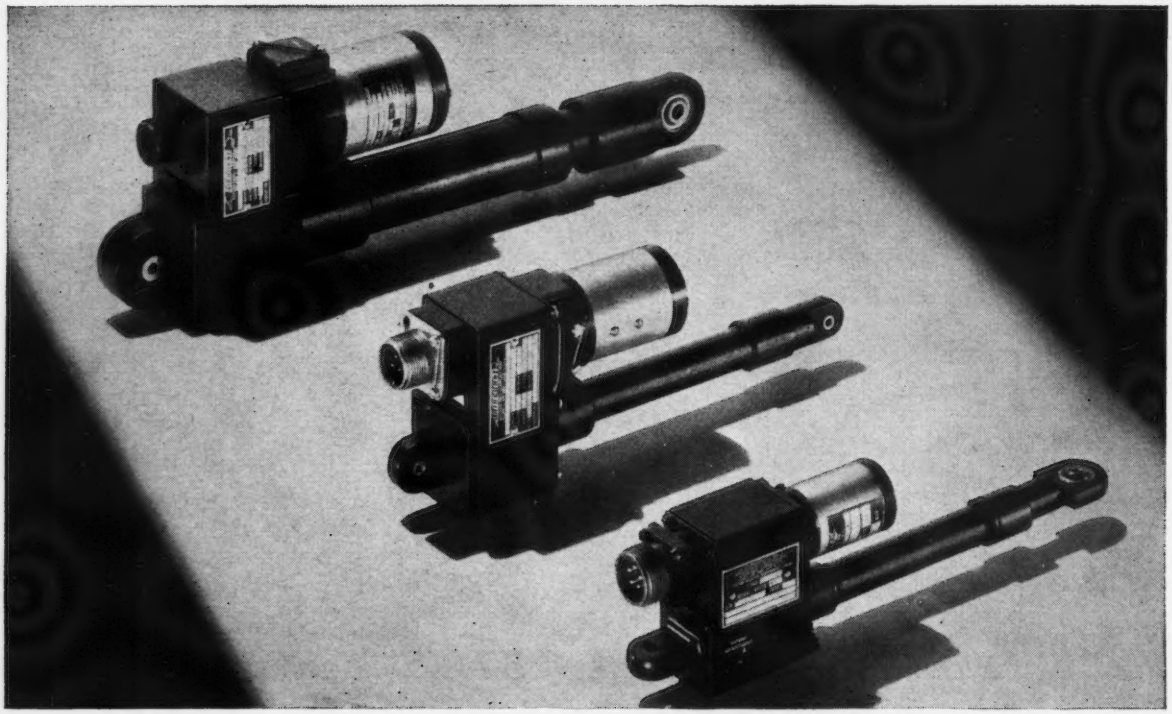

These new Airborne modular actuators—rated 2500, 650 and 350 lb., top to bottom —are not standard in the usual sense. Rather, they are merely three examples of the hundreds of different linear actuator packages that can be made up from Airborne's new line of standard, interchangeable actuator components.

New Airborne modular design concept simplifies actuator selection

Airborne's new modular actuators represent a completely fresh design approach. Whereas in the past we offered a line of standard linear actuators, we now offer a line of standard actuator *components* grouped in three broad operating capacity classifications: L12, L16 and L20. All components within a given classification are interchangeable.

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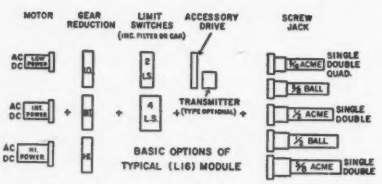
For more information, write for new Catalog 57A.



Airborne modular actuator classification L16 is composed of 22 standard, interchangeable components. Over 100 different linear actuators, ranging from 350 to 1500 lb. max. op. cap., can be assembled from these 22 components.

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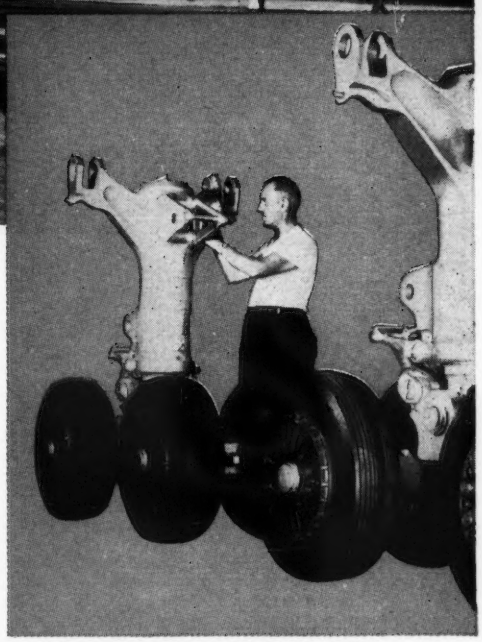

The photo above graphically illustrates the size of the landing gear in the compressed position.

ENGINEERING OPPORTUNITIES

Interesting positions are open for stress engineers and laboratory technicians. Write to: Director of Engineering, Jarry Hydraulics, 4384 St. Denis St., Montreal 18.

Designers and manufacturers of landing gear and other hydraulic components for modern aircraft, including: Argus, CF-105, CS-2F-1, F-86, T-33, Beaver, Otter.

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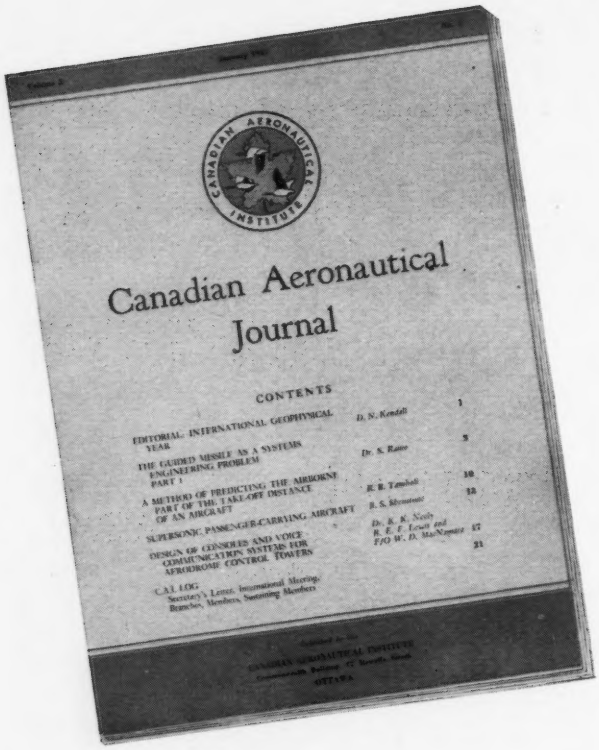
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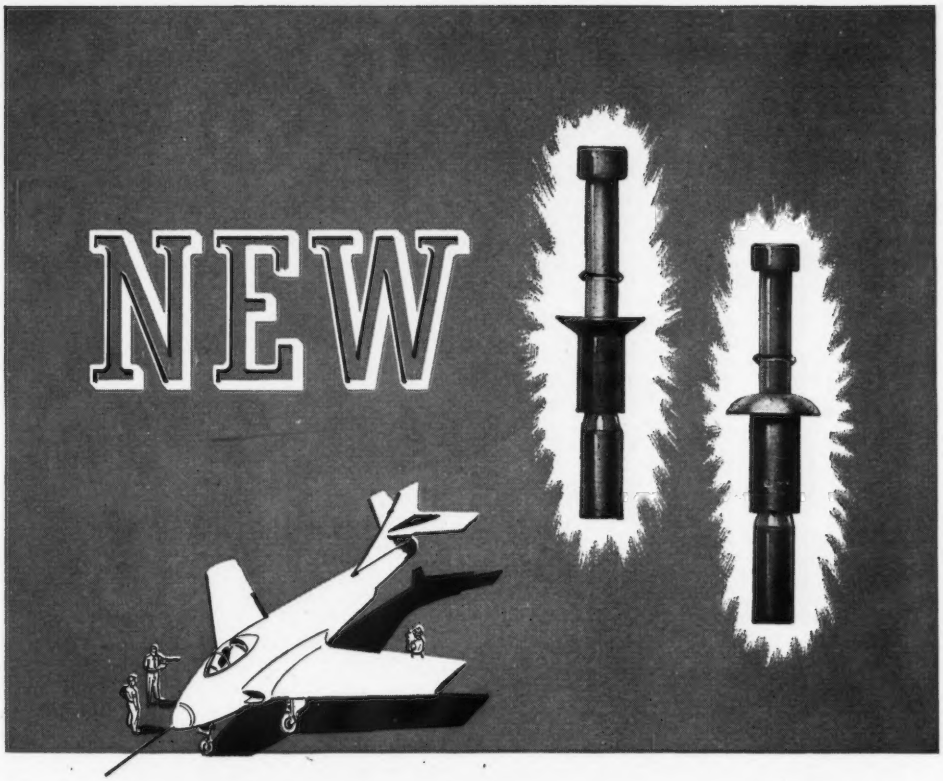

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A new, more effective fastener for the aircraft industry has been developed and is now being produced at the Cherry Rivet plant in Santa Ana, California. Designated the Cherry "700", the new rivet provides a wide grip range, positive hole fill, high clinch, uniform stem retention and permits 100% positive inspection.

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